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ATLAS OF CLOUD-FREE LINE-OF-SIGHT PROBABILITIES. PART 1. GERMANY

Iver A. Lund, et al

Air Force Cambridge Research Laboratories
Hanscom Air Force Base, Massachusetts

8 May 1975

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Atlas of Cloud-Free Line-of-Sight Probabilities

Part 1: Germany

IVER A. LUND
DONALD D. GRANTHAM
CLARENCE B. ELAM, Jr.

8 May 1975

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This is the first part of a planned Northern Hemisphere atlas of probabilities of cloud-free lines-of-sight between the earth and space, and the earth and an altitude of 2500 m (8200 ft). The probabilities are for the mid-season months—January, April, July, and October; four times of the day—0000-0200 LST, 0600-0800 LST, 1200-1400 LST, and 1800-2000 LST; and four elevation angles—10°, 30°, 50°, and 90°.

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Atlas of Cloud-Free Line-of-Sight Probabilities
Part 1: Germany

1. INTRODUCTION

The increased use of optical, infrared, and microwave observing and transmitting devices has resulted in a greater demand for information on humidity, haze, clouds, and precipitation. The Air Force Cambridge Research Laboratories (AFCRL)* Design Climatology Branch (LKI), Hanscom AFB, MA 01731, and the USAF Environmental Technical Applications Center (ETAC)*, Scott AFB, Illinois 62225 have responded to this demand by collecting special observations, developing models for estimating the desired information in the absence of direct observations, and processing vast quantities of data.

One of the items frequently requested is information on the probability of a cloud-free line-of-sight (CFLOS) between a specific point on the surface of the earth and an aircraft or an object in space. A large volume of data has been processed in response to these requests.

AFCRL and ETAC are endeavoring to prepare a Northern Hemisphere atlas from these data. Because this is a very time-consuming effort, we have decided to prepare this atlas in sections as data become available. This first section, Germany, is a very small part of the entire effort.

(Received for publication 8 May 1975)

*Department of Defense organizations and contractors are encouraged to contact AFCRL or ETAC for further information on line-of-sight probabilities. Probabilities as a function of altitude and persistence, recurrence and joint probabilities are also available.

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2. THE MODEL

Lund and Shanklin[1] developed models for estimating probabilities of CFLOS through the atmosphere at any desired elevation angle and geographical location. The models require a knowledge of sky-cover climatology for the locations.

The model used to estimate CFLOS probabilities through the entire atmosphere can be expressed as follows:

$$ {}_{\alpha}\hat{P}_1 = {}_{\alpha}C_s K_1 \qquad (1) $$

where ${}_{\alpha}\hat{P}_1$ is a column vector of α rows, one row for each angle considered; ${}_{\alpha}C_s$ is a matrix of α rows and s columns, one column for each sky cover category; and ${}_{s}K_1$ is a column vector of s rows. The $\hat{P}$ values are estimates of CFLOS probabilities, the C values are CFLOS probabilities at angles α given k tenths of cloudiness, and the K values are probabilities of each k tenths of cloudiness.

The ${}_{\alpha}C_s$ matrix used for this paper is given in Table 1.

Table 1. Probabilities of Cloud-Free Lines-of-Sight as a Function of Elevation Angle and Observed Total Sky Cover in Tenths. This is the ${}_{\alpha}C_s$ Matrix

		Sky Cover (tenths)										
		0	1	2	3	4	5	6	7	8	9	10
Elevation Angle (degrees)	90	1.00	0.97	0.92	0.87	0.81	0.77	0.70	0.62	0.48	0.31	0.08
	50	0.99	0.96	0.90	0.85	0.78	0.73	0.64	0.58	0.45	0.29	0.08
	30	0.98	0.93	0.86	0.80	0.73	0.66	0.57	0.50	0.38	0.24	0.06
	10	0.97	0.86	0.76	0.65	0.55	0.47	0.39	0.32	0.24	0.16	0.03

3. AN EXAMPLE

The climatic record of sky cover at Rhein-Main Apt, Frankfurt, Germany, shows that 0/10, 1/10, ..., 9/10, and 10/10 sky cover was reported 6.0, 3.0, 0.7, 2.8, 3.6, 2.5, 4.7, 1.9, 6.5, 18.6, and 49.8 percent of the time, respectively, between 12-14 LST during January 1947 through 1970. Performing the matric multiplication, we obtain:

1. Lund, I.A., and Shanklin, M.D. (1973) Universal methods for estimating probabilities of cloud-free lines-of-sight through the atmosphere, J. Appl. Meteorol. 12(No. 1):28-35.

$$ {}_{\alpha}\hat{P}_1 = \begin{bmatrix} 1.00 & 0.97 & \cdots & 0.31 & 0.08 \\ 0.99 & . & & . & 0.08 \\ 0.98 & . & & . & 0.06 \\ 0.97 & . & & . & 0.03 \end{bmatrix} \begin{bmatrix} 0.060 \\ 0.030 \\ . \\ . \\ 0.186 \\ 0.498 \end{bmatrix} = \begin{bmatrix} 0.340 \\ 0.329 \\ 0.293 \\ 0.224 \end{bmatrix} . \qquad (2) $$

The computations show that there is about 34.0% probability of a CFLOS at Rhein-Main looking toward the zenith (90°), and a 32.9%, 29.3%, and 22.4% probability of a CFLOS at 50°, 30°, and 10°, respectively.

4. CFLOS PROBABILITIES BELOW 8200 ft (2500 m)

Estimates of CFLOS probabilities between the earth's surface and a height of 8200 ft requires knowledge of the distribution of cloud amount below 8200 ft. The standard synoptic cloud group, $N_h C_L h C_M C_H$, where N_h is the total amount of low clouds (N_h is reported in octas) or, in the absence of low clouds, the amount of middle clouds, and h is the height of the lowest cloud, is used to determine this distribution (h is reported according to WMO Code 1600). Each observation is checked to determine the height of the lowest cloud, h. If h is coded as 8 or less, the amount of cloud reported for N_h is determined. If h is 9, no clouds are present below 8200 ft. The resulting distribution of cloud amounts below the level of 8200 ft is multiplied by the ${}_{\alpha}C'_s$ matrix to determine ${}_{\alpha}\hat{P}'_1$, the probability of a CFLOS between the surface and 8200 ft.

$$ {}_{\alpha}\hat{P}'_1 = {}_{\alpha}C'_s K'_1 \qquad (3) $$

where ${}_{\alpha}C'_s$ is the matrix given in Table 2 and the K′ column vector is the sky cover below 8200 ft in octas.

Table 2. Probabilities of Cloud-Free Lines-of-Sight as a Function of Elevation Angle and Observed Total Sky Cover, in Octas. This is the ${}_{\alpha}C'_s$ Matrix

		Sky Cover (octas)								
		0	1	2	3	4	5	6	7	8
Elevation Angle (degrees)	90	1.00	0.96	0.89	0.83	0.77	0.68	0.55	0.35	0.08
	50	0.99	0.94	0.87	0.81	0.73	0.63	0.52	0.33	0.08
	30	0.98	0.92	0.83	0.75	0.66	0.55	0.43	0.28	0.06
	10	0.97	0.84	0.72	0.58	0.47	0.38	0.28	0.17	0.03

5. THE STATIONS

Table 3 lists stations from which long records of hourly sky cover observations are available for at least part of the day. CFLOS probabilities were computed for these stations, which are shown in Figure 1.

Table 3. Station Locator Table

Map Number	WMO Number (Call Letters)	Station Name	Lat. (°N)	Long. (°E)	Alt. (m)
1	10035	Schleswig	54-32	09-33	44
2	10202	Emden/Wolthusen	53-22	07-13	0
3	10147	Hamburg/Fuhlsbuttel	53-38	10-00	16
4	10170	Warnemunde	54-11	12-05	4
5	10313	Munster	51-58	07-36	64
6	10338	Hannover	52-28	09-42	55
7	10279	Nuesterlitz	53-21	13-05	64
8	10513	Koln/Bonn	50-52	07-09	91
9	10438	Kassel	51-19	09-29	158
10	10453	Brocken	51-48	10-37	1142
11	10361	Magdeburg	52-06	11-34	79
12	10384	Berlin/Tempelhof AB	52-28	13-24	50
13	10610	Bitburg AB	49-57	06-34	374
14	10607	Spangdahlem AB	49-59	06-42	365
15	10616	Hahn AB/Hunsruck	49-57	07-16	502
16	EDEH	Bad Kreuznach AAF	49-52	07-55	105
17	EDOT	Finthen AAF	49-58	08-09	231
18	10633	Weisbaden AB	50-03	08-20	140
19	10636	Rhein-Main APT/Frankfurt	50-02	08-34	112
20	10642	Hanau AAF	50-10	08-57	112
21	EDEX	Fulda AAF	50-32	09-38	305
22	10546	Kaltennordheim	50-38	10-09	487
23	10567	Gera/Leumnitz	50-53	12-08	300
24	10470	Leipzig/Mockau	51-24	12-25	67
25	10488	Dresden	51-08	13-46	230
26	07089	Chambley, France/AB	49-02	05-53	265
27	10619	Baumholder AAF	49-38	07-18	426
28	10714	Zweibrucken RCAF STN	49-13	07-24	343
29	10614	Ramstein AB	49-26	07-35	238
30	10712	Sembach AB	49-31	07-52	321
31	EDOR	Sandhofen/Coleman AAF	49-34	08-28	108
32	10734	Heidelberg AAF	49-24	08-39	1010
33	10657	Wertheim AAF	49-46	09-29	338
34	10655	Wurzburg	49-48	09-54	259
35	10659	Kitzingen AAF	49-45	10-12	213
36	10752	Illesheim AAF	49-28	10-23	325
37	10755	Katterbach/Ansbach AAF	49-18	10-35	413
38	EDEW	Nurnberg/Furth	49-30	10-57	302
39	10687	Grafenwohr AAF	49-42	11-57	415
40	EDIH	Hohenfels AAF	49-13	11-50	442
41	10738	Stuttgart/Echterdingen APT	48-41	09-13	396
42	10745	Schwaebisch Hall AAF	49-07	09-47	398
43		Gablingen, AAF	48-27	10-52	502
44	10869	Erding Air Station	48-19	11-57	460
45	10866	Munchen	48-08	11-42	528
46	10971	Bad Tolz AAF	47-46	11-36	716
57	10803	Freiburg	48-00	07-51	269

6. THE MAPS

A total of 66 maps are included in this paper: one station locator map, Figure 1; one map for each of the four mid-season months (Jan-Apr-Jul-Oct), four 3-hour periods (00-02 LST, 06-08 LST, 12-14 LST, 18-20 LST), four elevation angles (10°, 30°, 50°, 90°), Figures 2 through 65; and a single map, Figure 66, depicting the extreme condition (the lowest probability for any of the above months and periods). In order to conserve space, the extreme condition is shown for the 30° elevation angle only.

All of the CFLOS probability values plotted on the maps below the station locations were computed as shown in Eq. (2); however, the ${}_{s}K_{1}$ column vector was changed with every station, month, or 3-hour time period change. The values plotted above the station location were computed through the use of Eq. (3). They are estimates of the probabilities of a CFLOS between the earth's surface and an altitude of 8200 ft. CFLOS probabilities were not plotted on the maps unless they were based on at least 300 sky-cover observations. Most of the probabilities are based on more than 900 sky-cover observations.

Because of the small area covered by the map and the few locations considered, an analysis of the CFLOS probabilities was not performed.

References

1. Lund, I.A., and Shanklin, M.D. (1973) Universal methods for estimating probabilities of cloud-free lines-of-sight through the atmosphere, J. Appl. Meteorol. 12(No. 1):28-35.

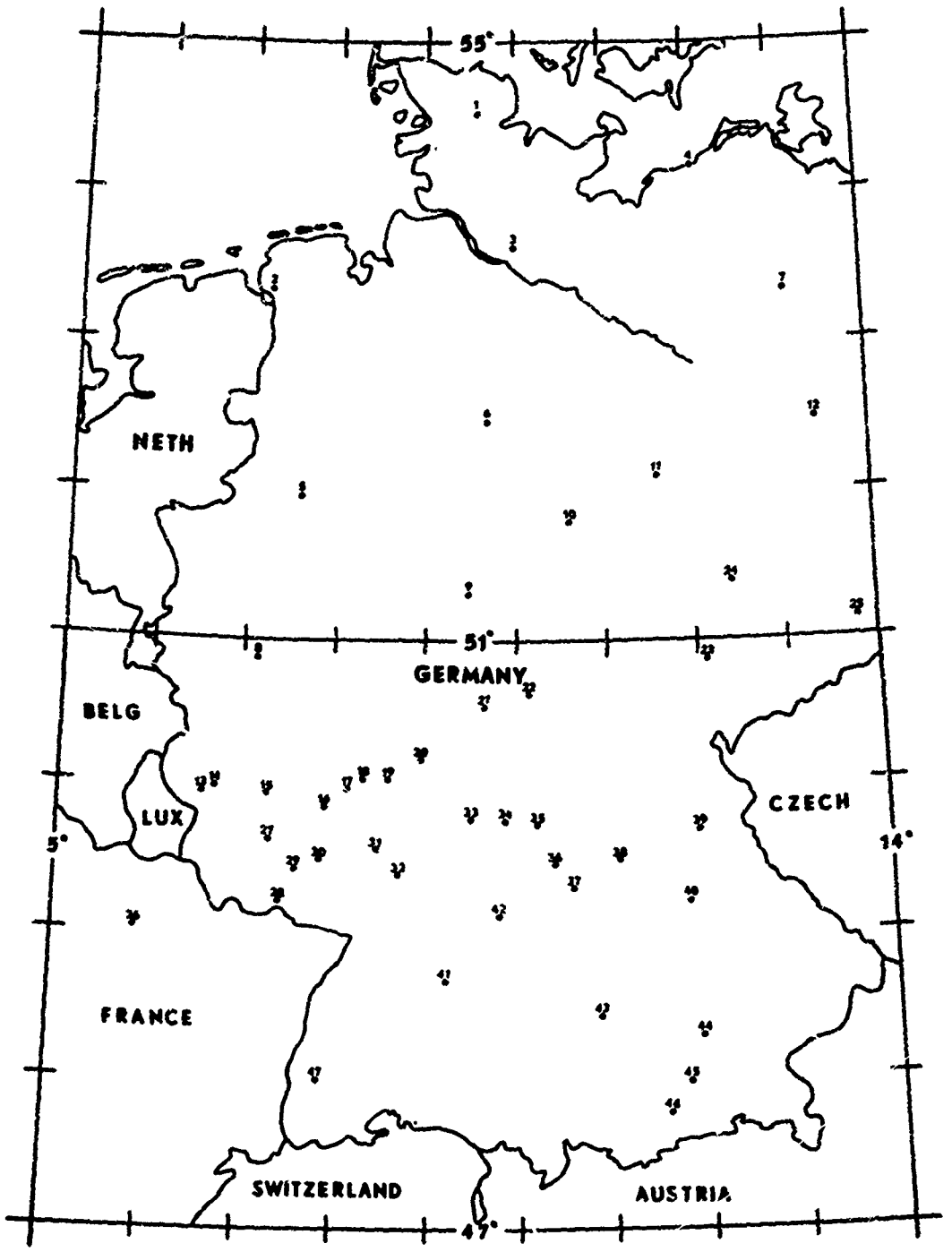

Figure 1. Station Locator Map

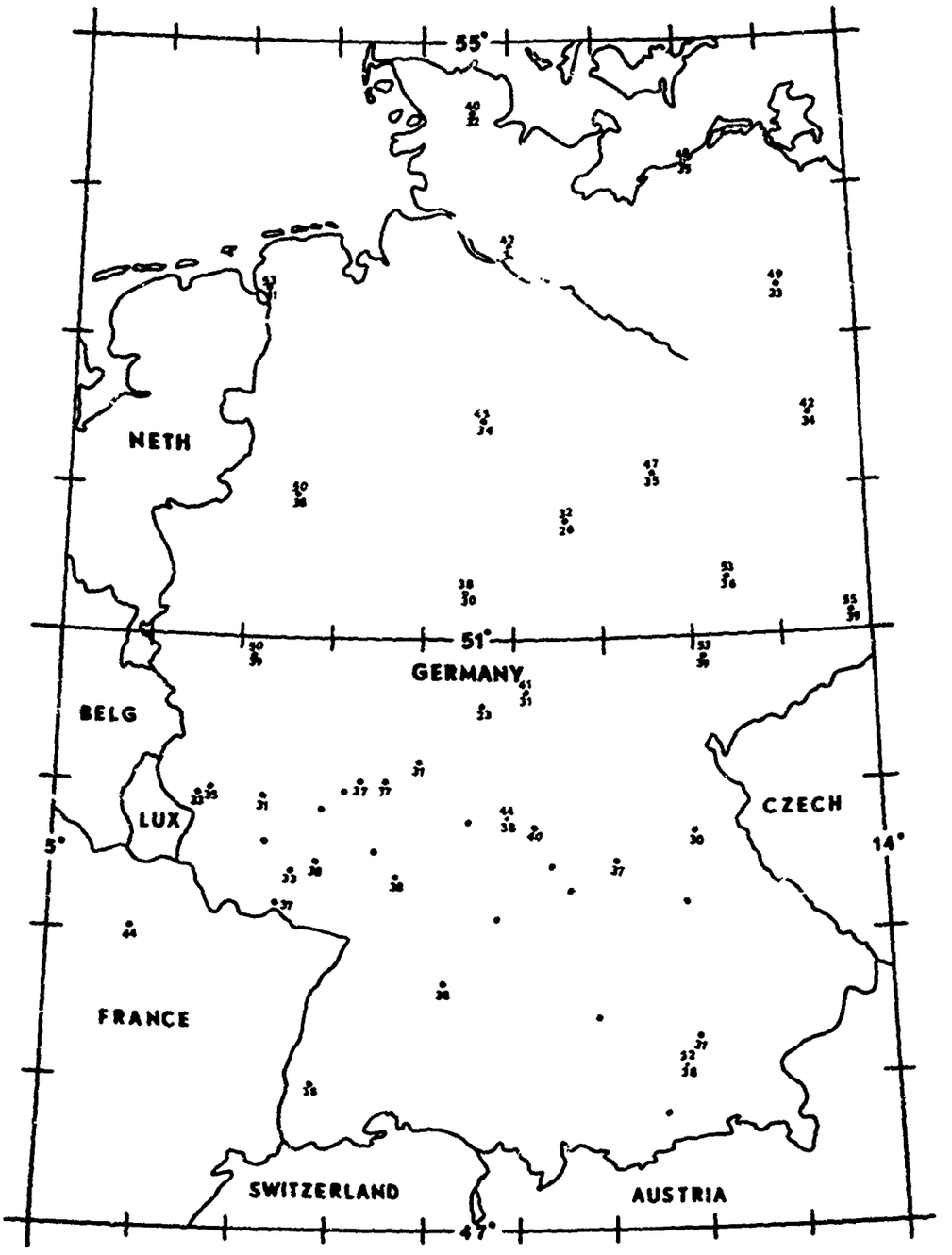

Figure 2. CFLOS Probabilities for Jan, 00-02 LST, 90° Elevation

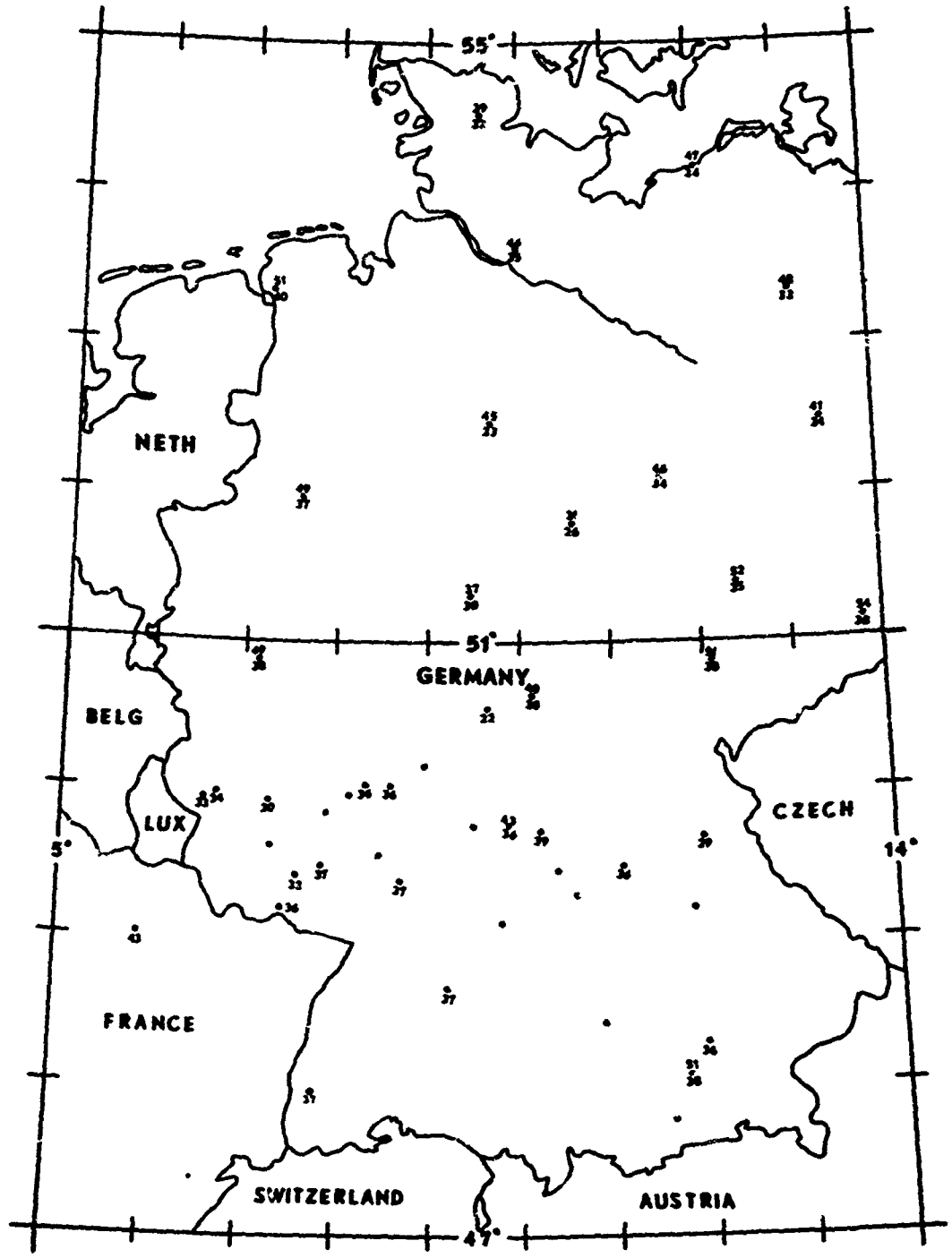

Figure 3. CFLOS Probabilities for Jan, 00-02 LST, 50° Elevation

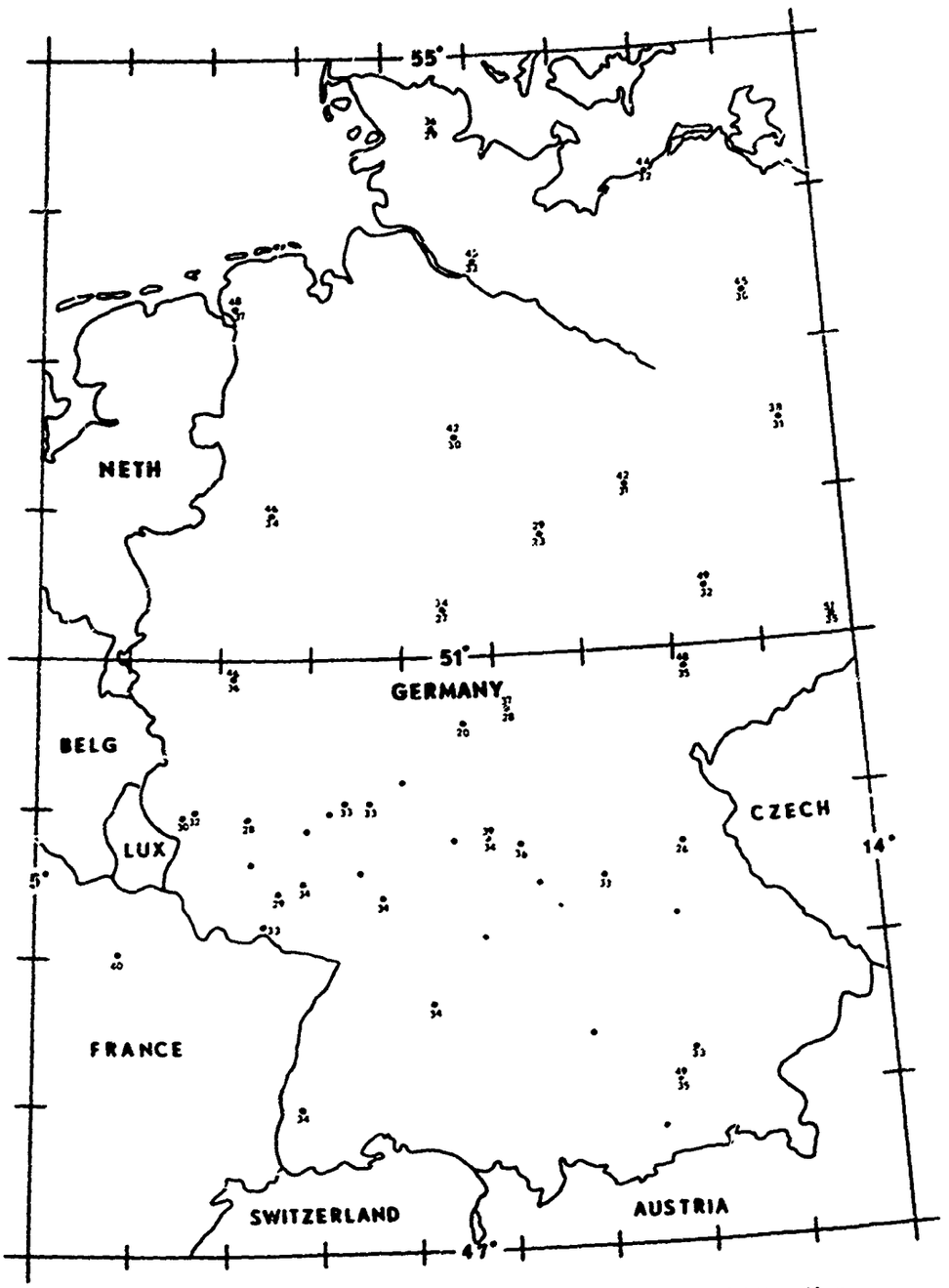

Figure 4. CFLOS Probabilities for Jan, 00-02 LST, 30° Elevation

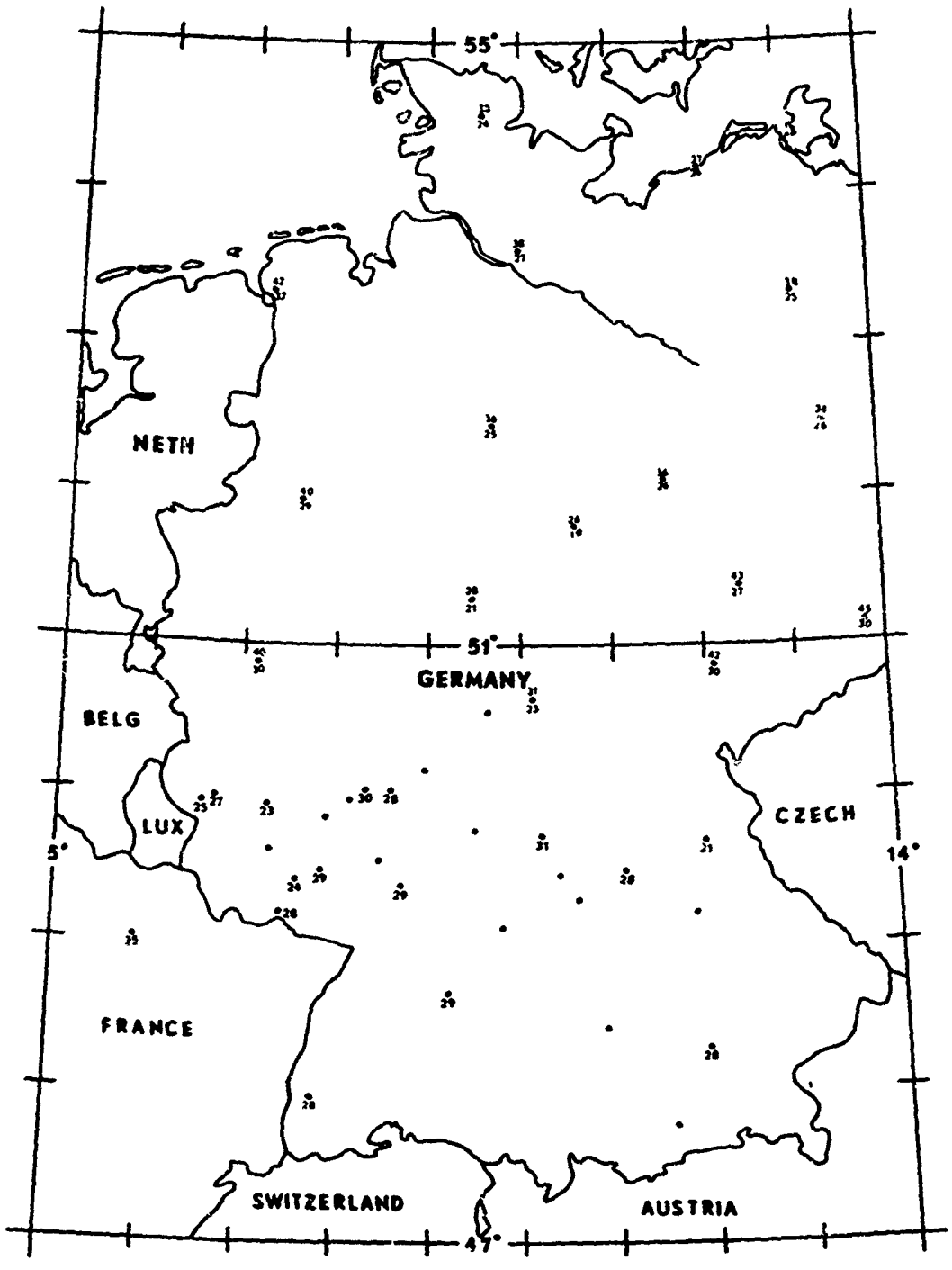

Figure 5. CFLOS Probabilities for Jan, 00-02 LST, 10° Elevation

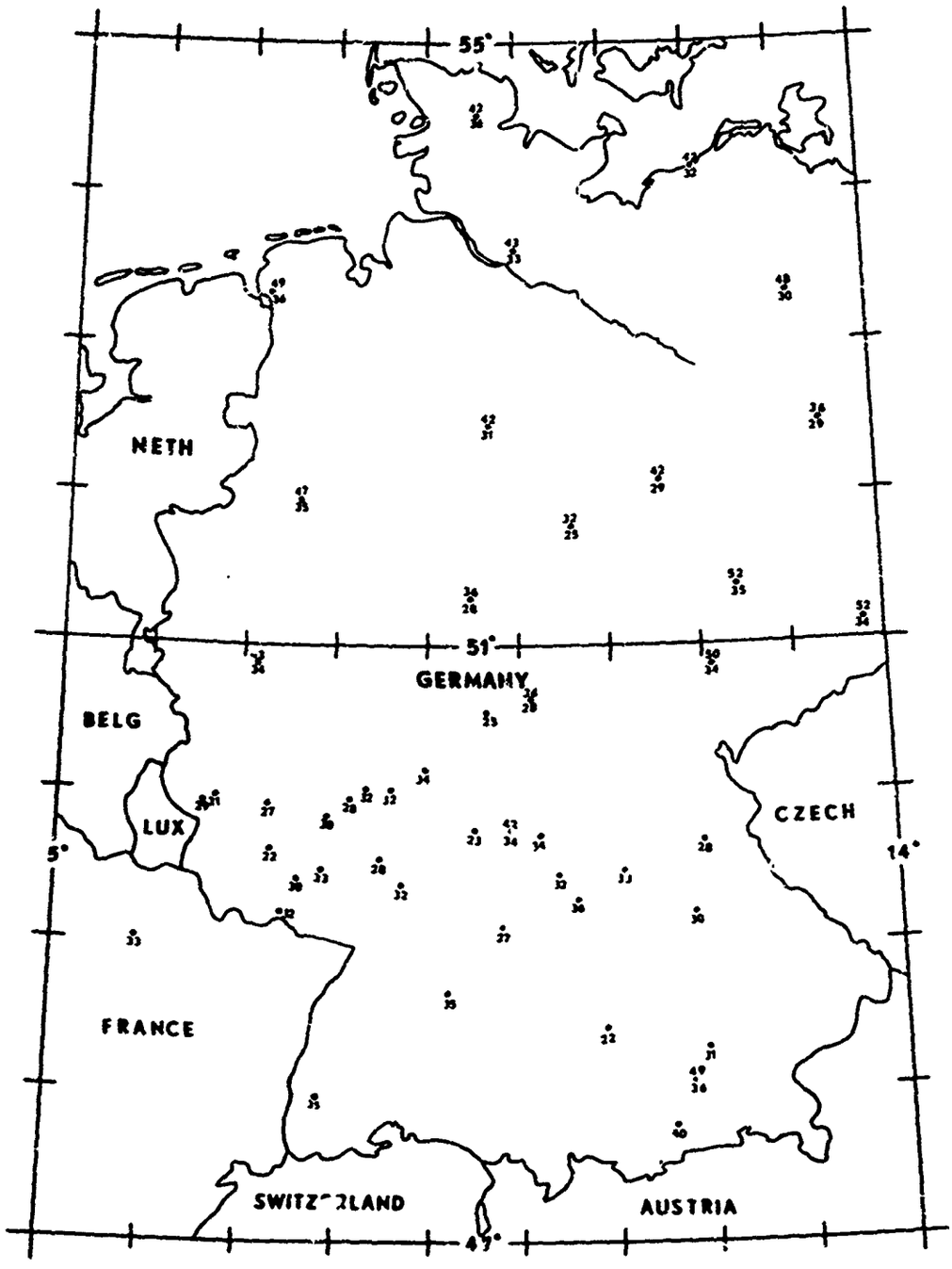

Figure 6. CFLOS Probabilities for Jan, 06-08 LST, 90° Elevation

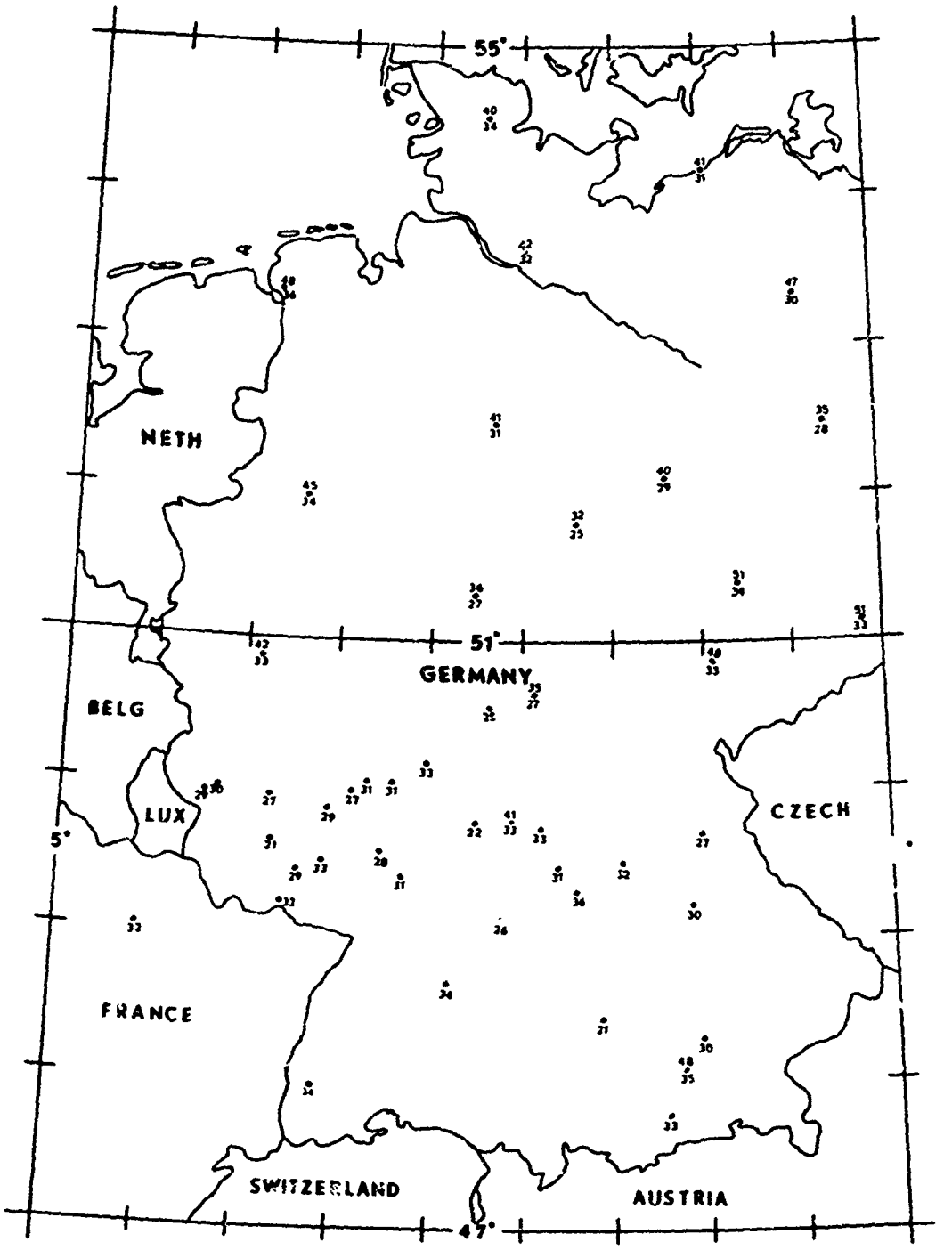

Figure 7. CFLOS Probabilities for Jan, 06-08 LST, 50° Elevation

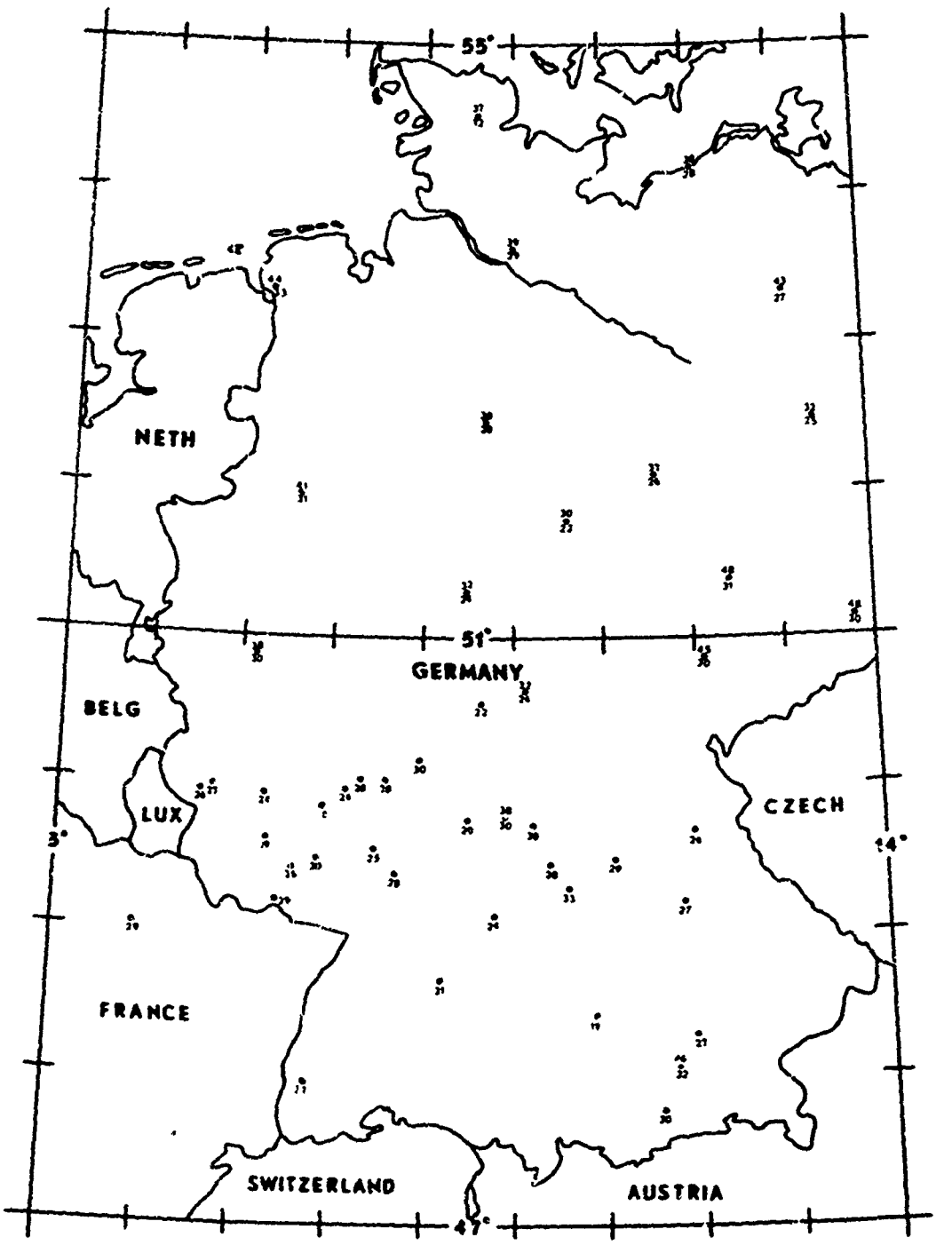

Figure 8. CFLOS Probabilities for Jan, 06-08 LST, 30° Elevation

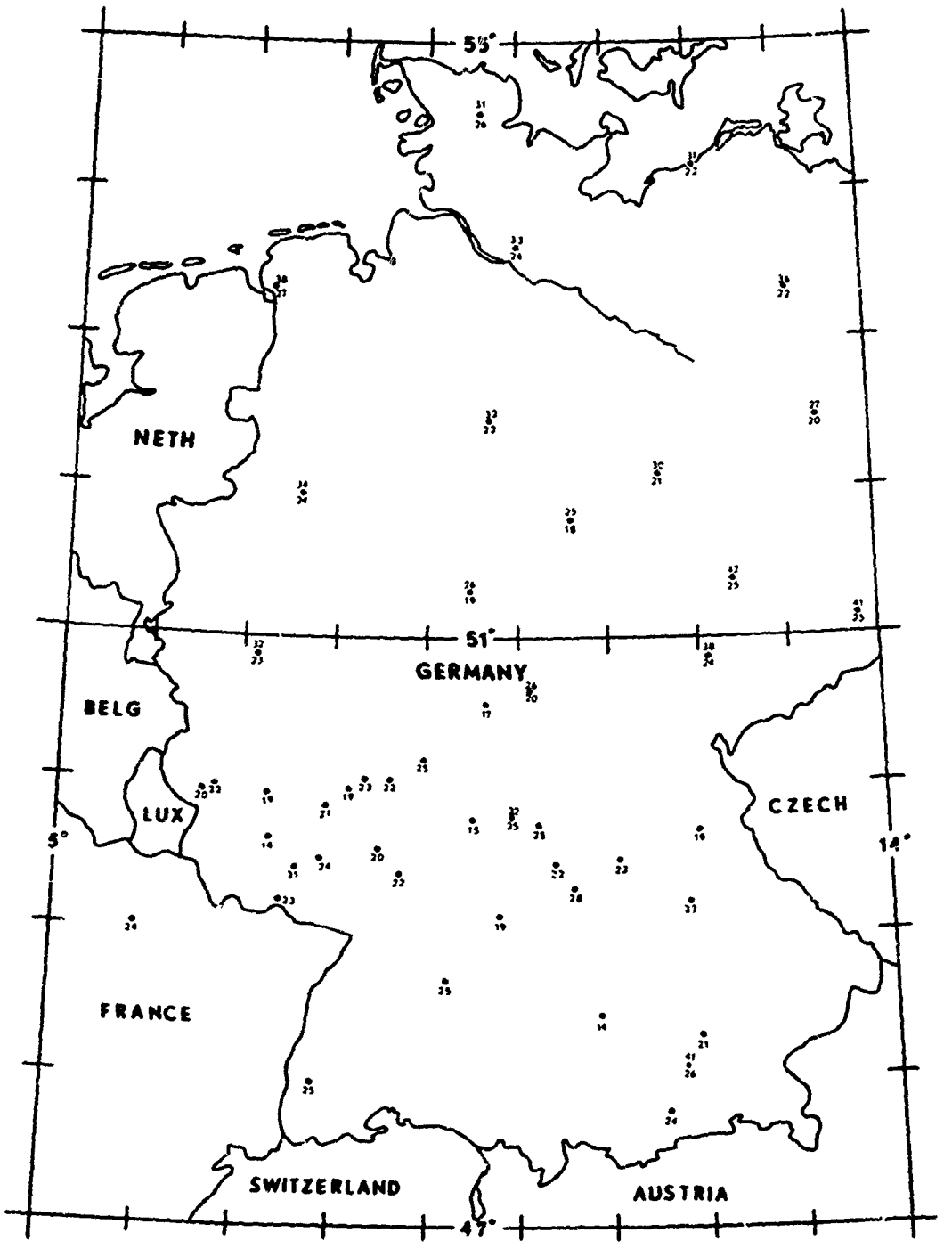

Figure 9. CFLOS Probabilities for Jan, 06-08 LST, 10° Elevation

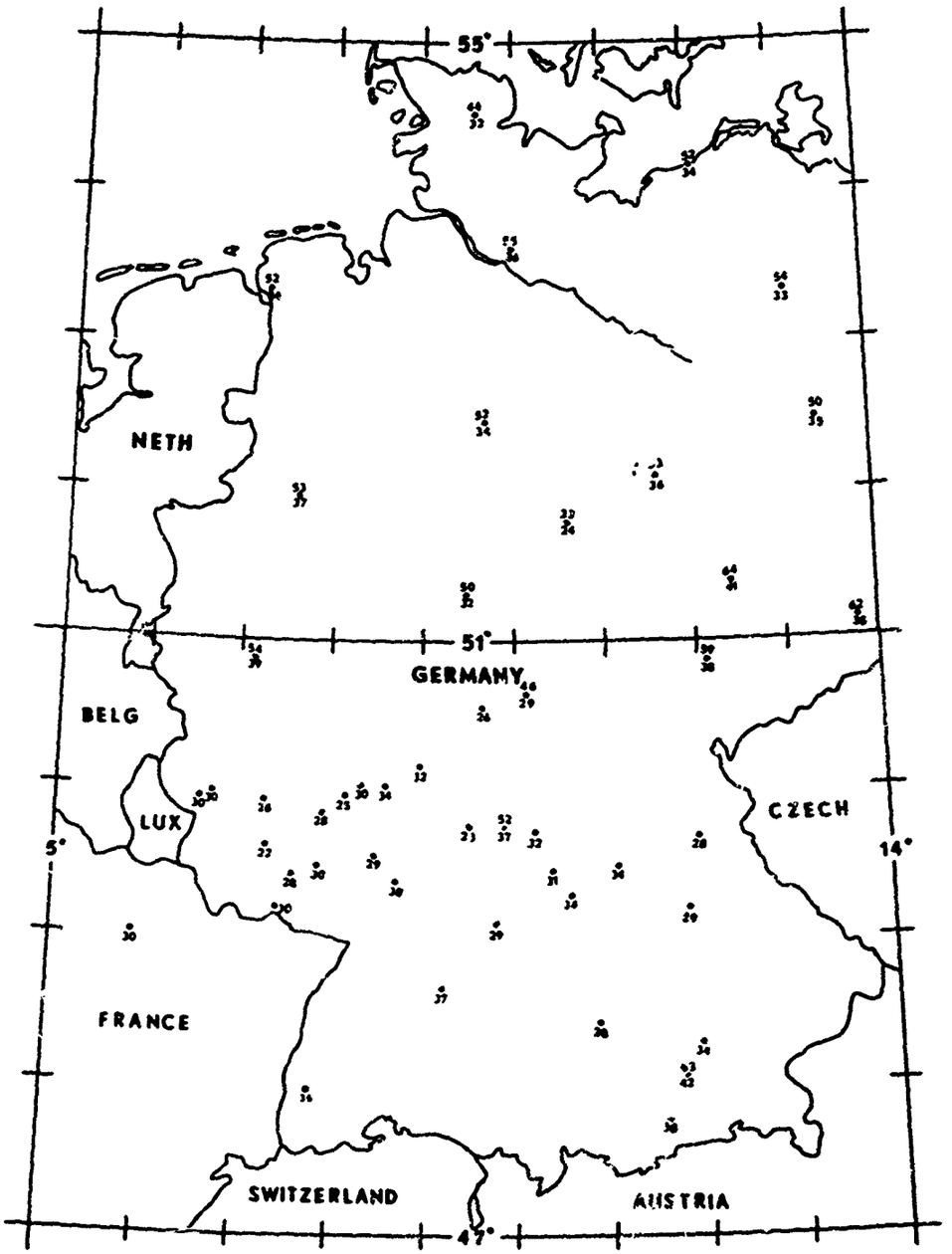

Figure 10. CFLOS Probabilities for Jan, 12-14 LST, 90° Elevation

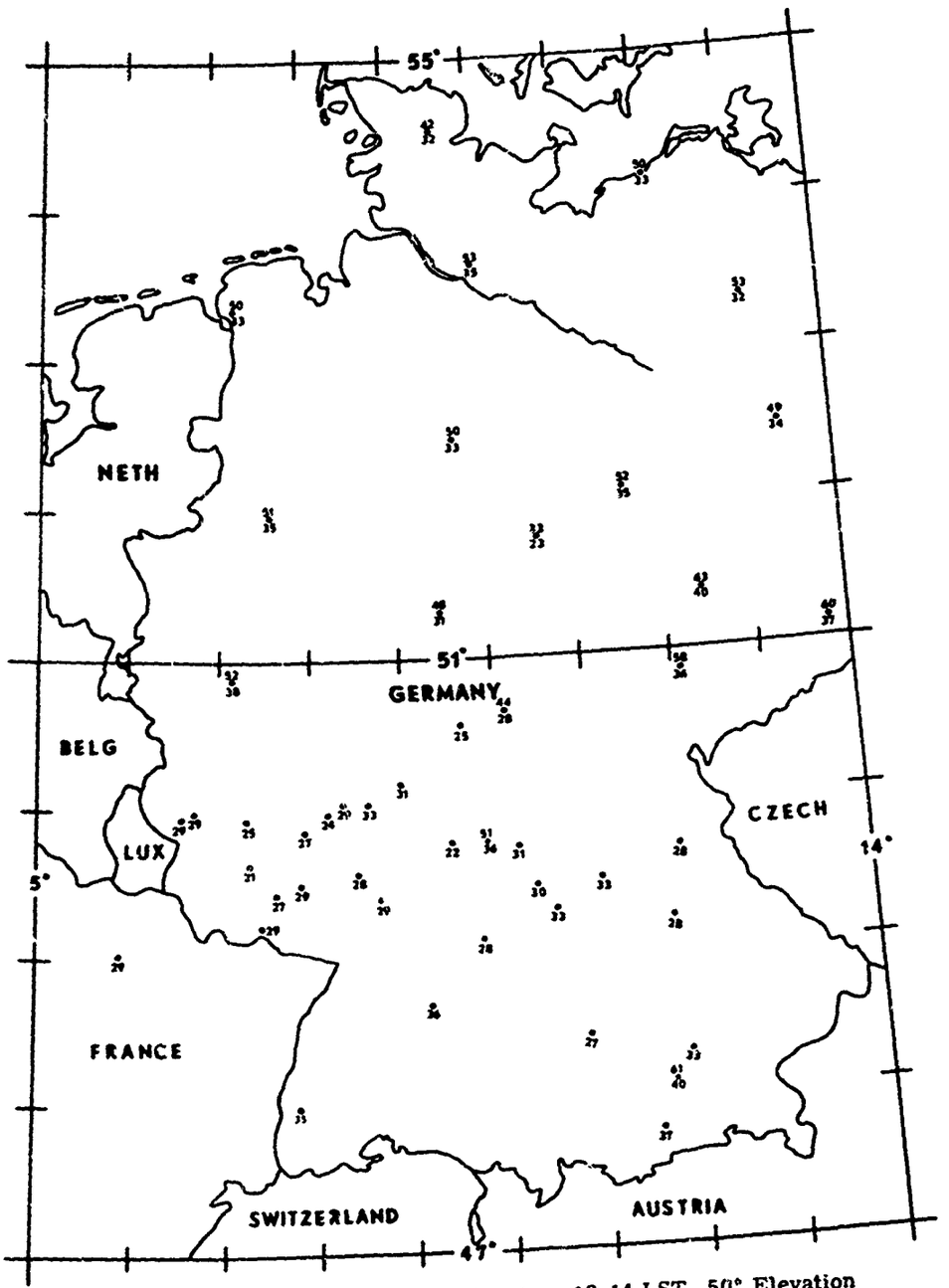

Figure 11. CFLOS Probabilities for Jan, 12-14 LST, 50° Elevation

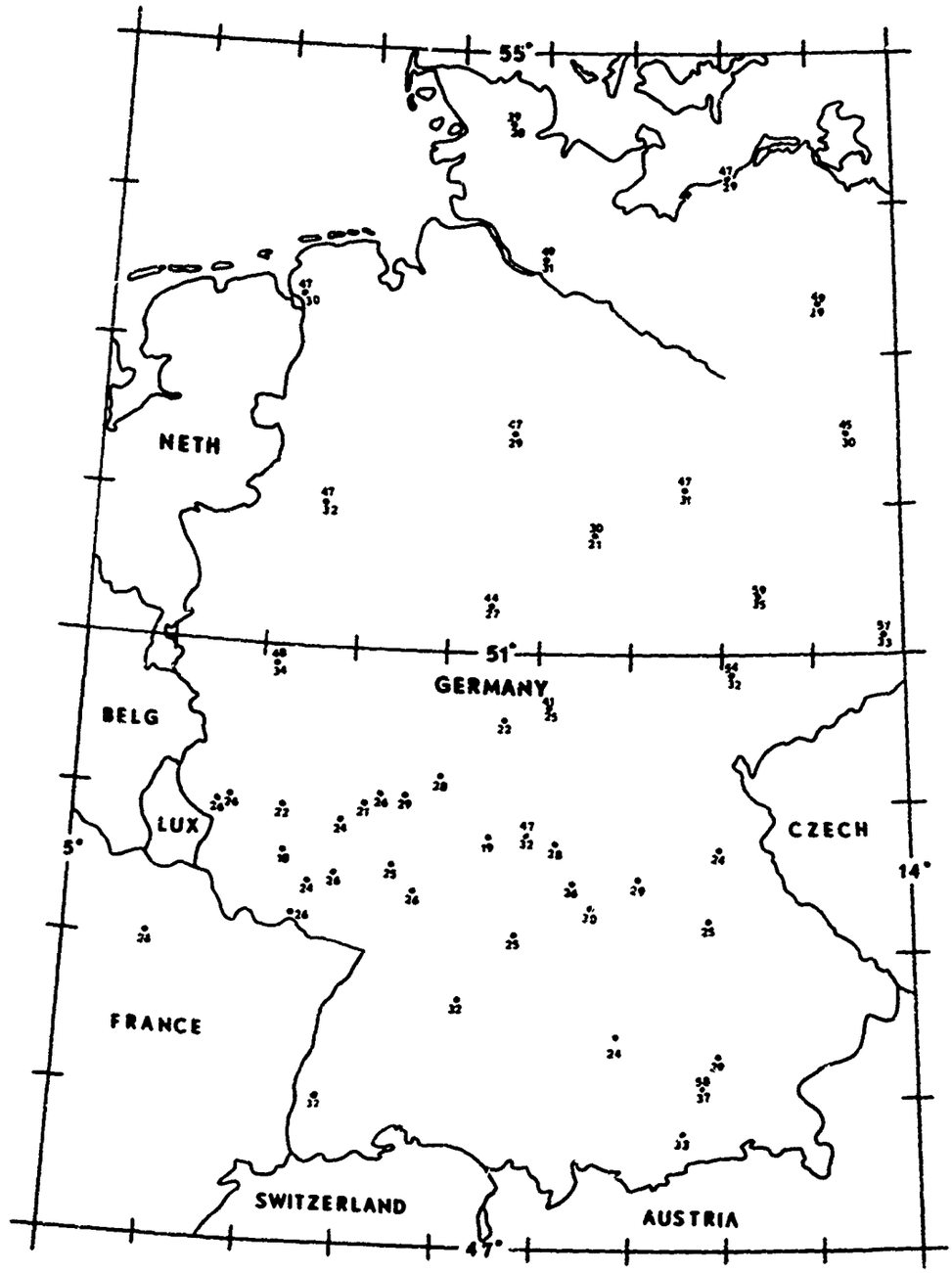

Figure 12. CFLOS Probabilities for Jan, 12-14 LST, 30° Elevation

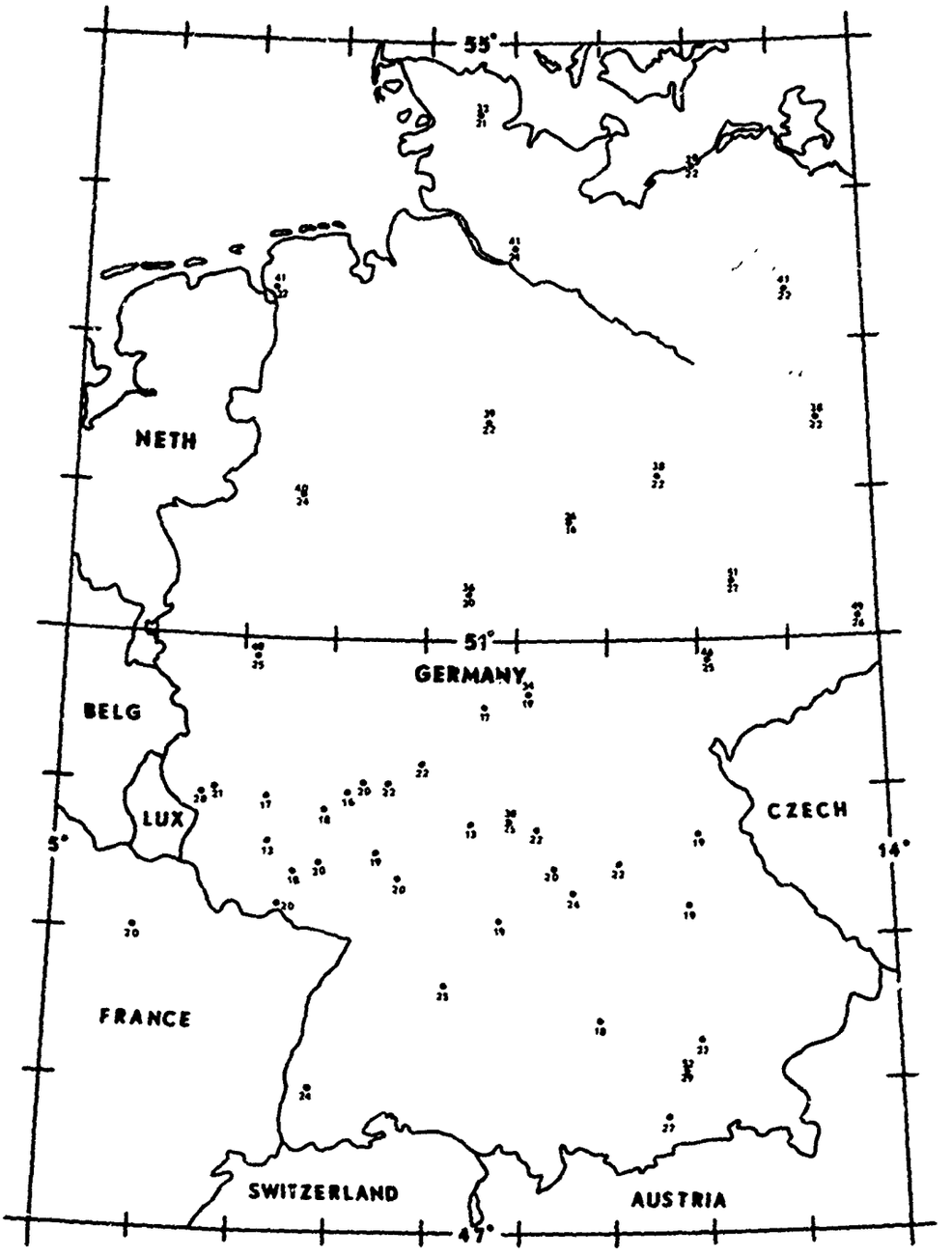

Figure 13. CFLOS Probabilities for Jan, 12-14 LST, 10° Elevation

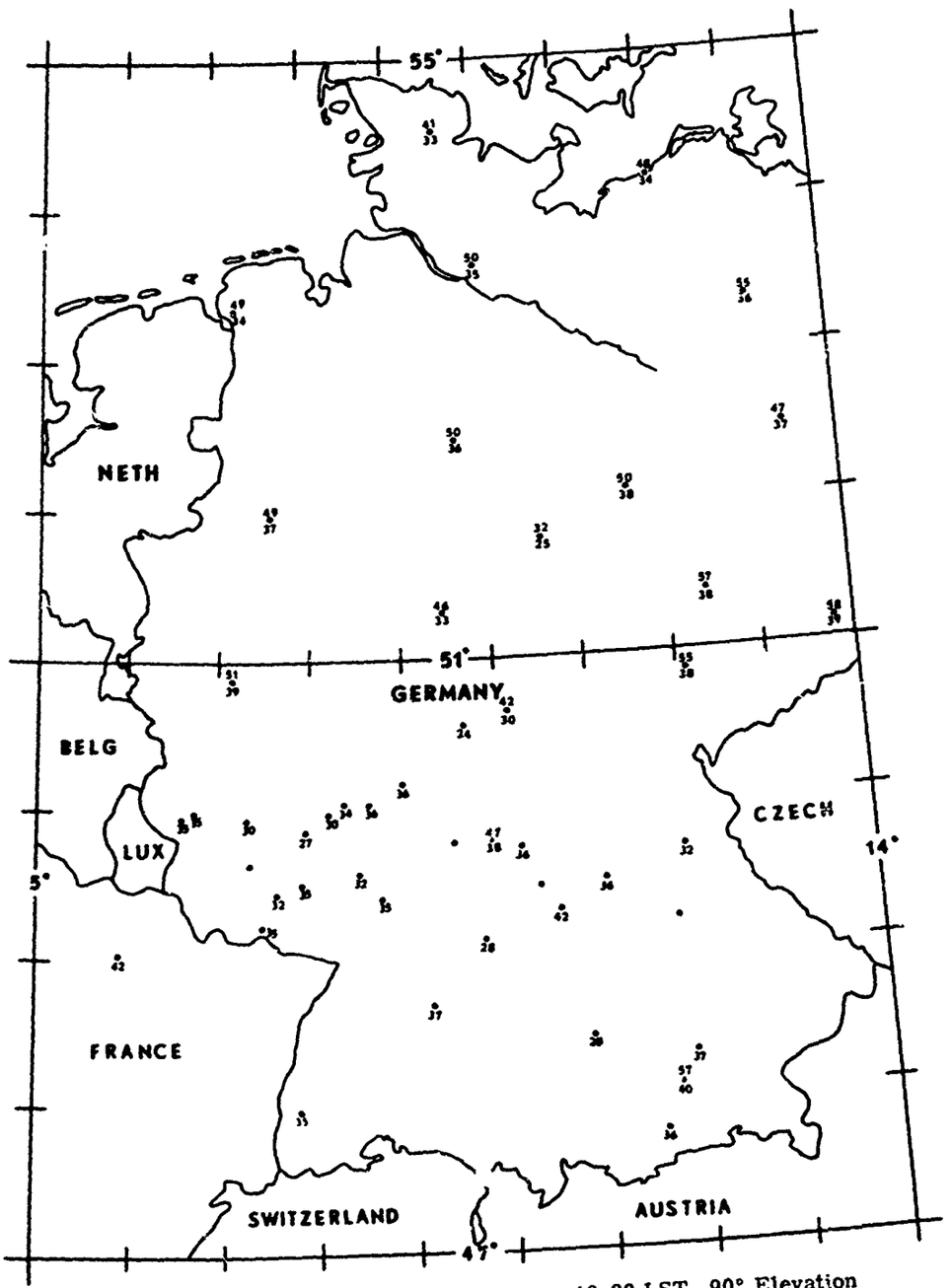

Figure 14. CFLOS Probabilities for Jan, 18-20 LST, 90° Elevation

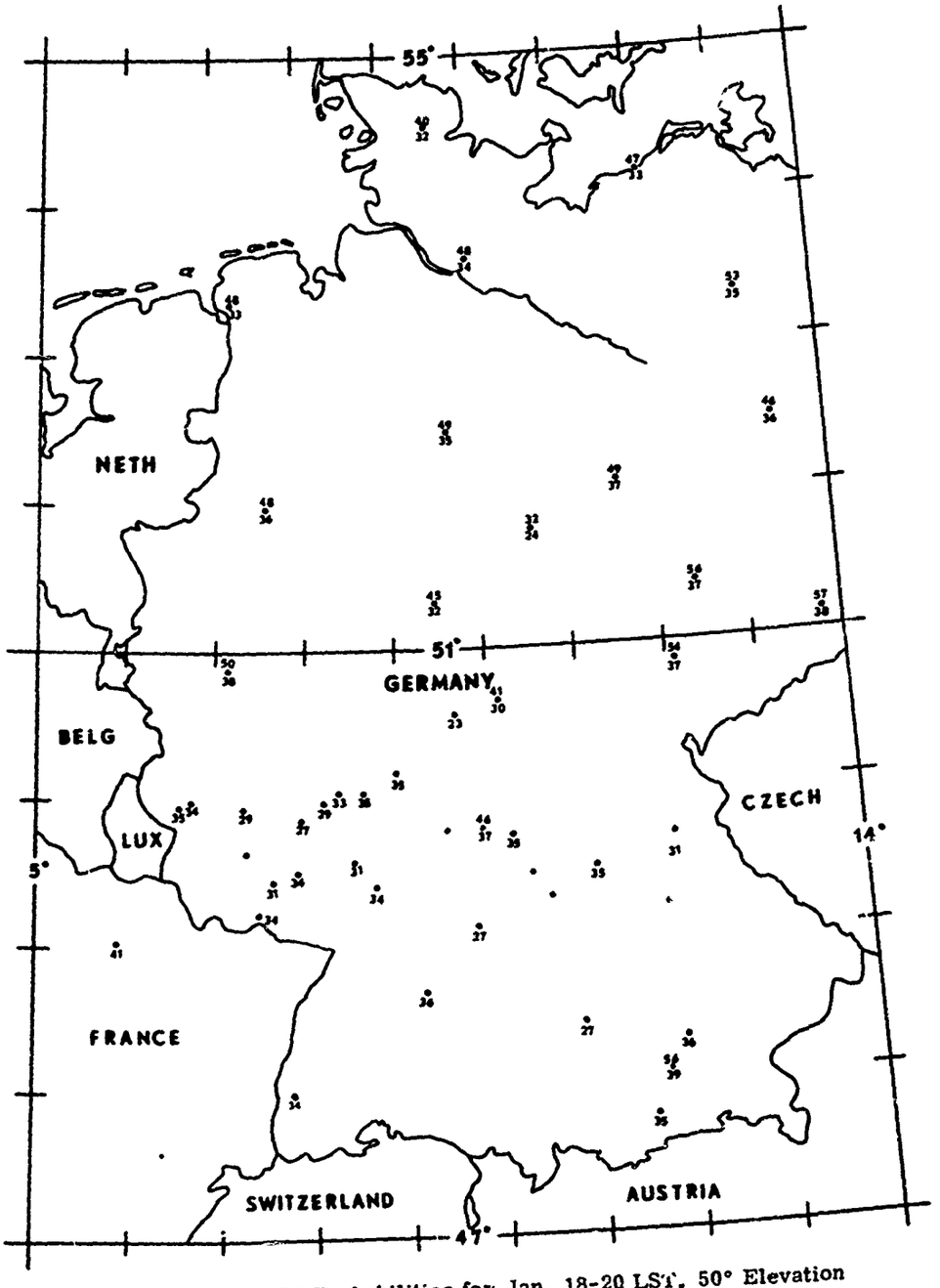

Figure 15. CFLOS Probabilities for Jan, 18-20 LST, 50° Elevation

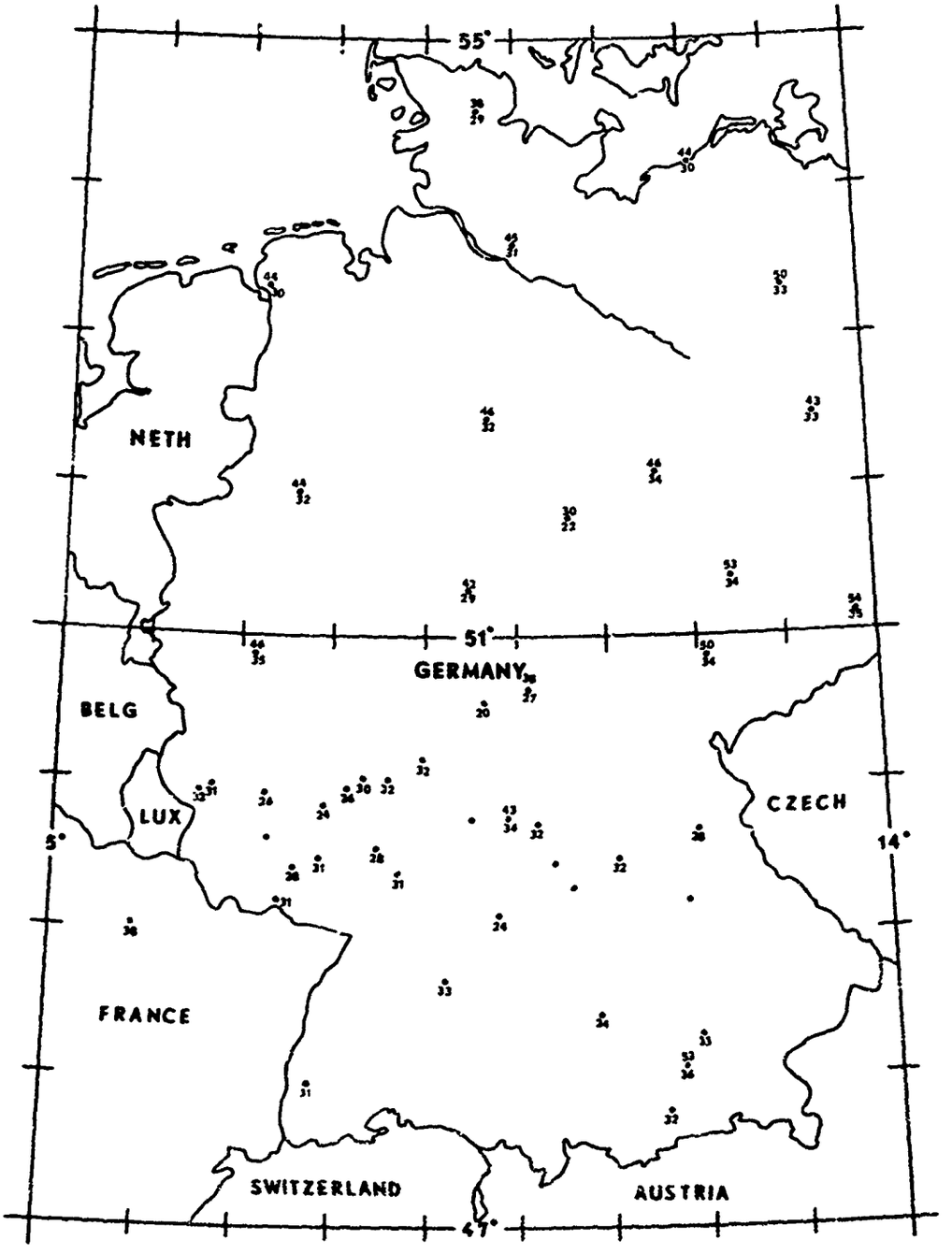

Figure 16. CFLOS Probabilities for Jan, 18-20 LST, 30° Elevation

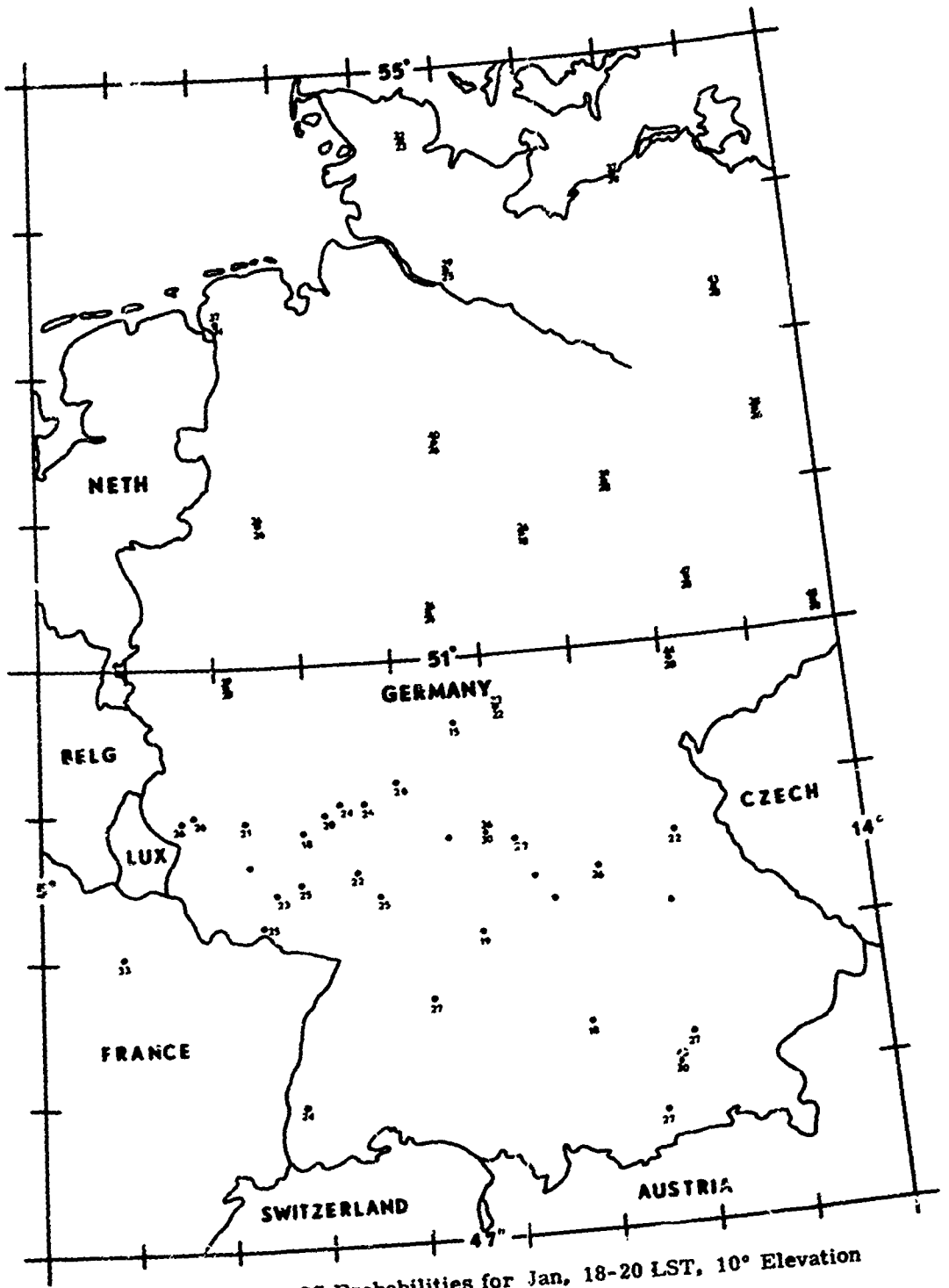

Figure 17. CFLOS Probabilities for Jan, 18-20 LST, 10° Elevation

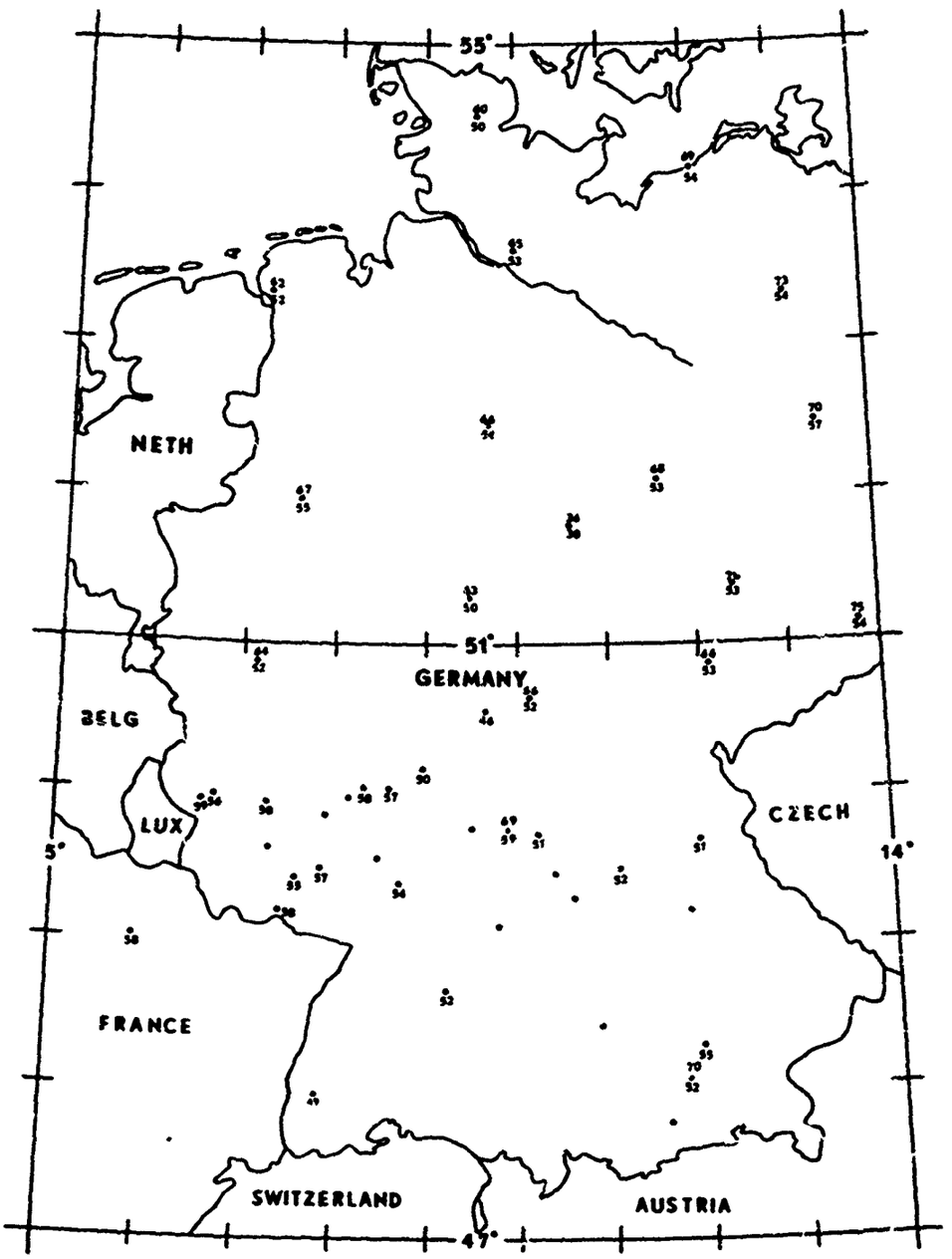

Figure 18. CFLOS Probabilities for Apr, 00-02 LST, 90° Elevation

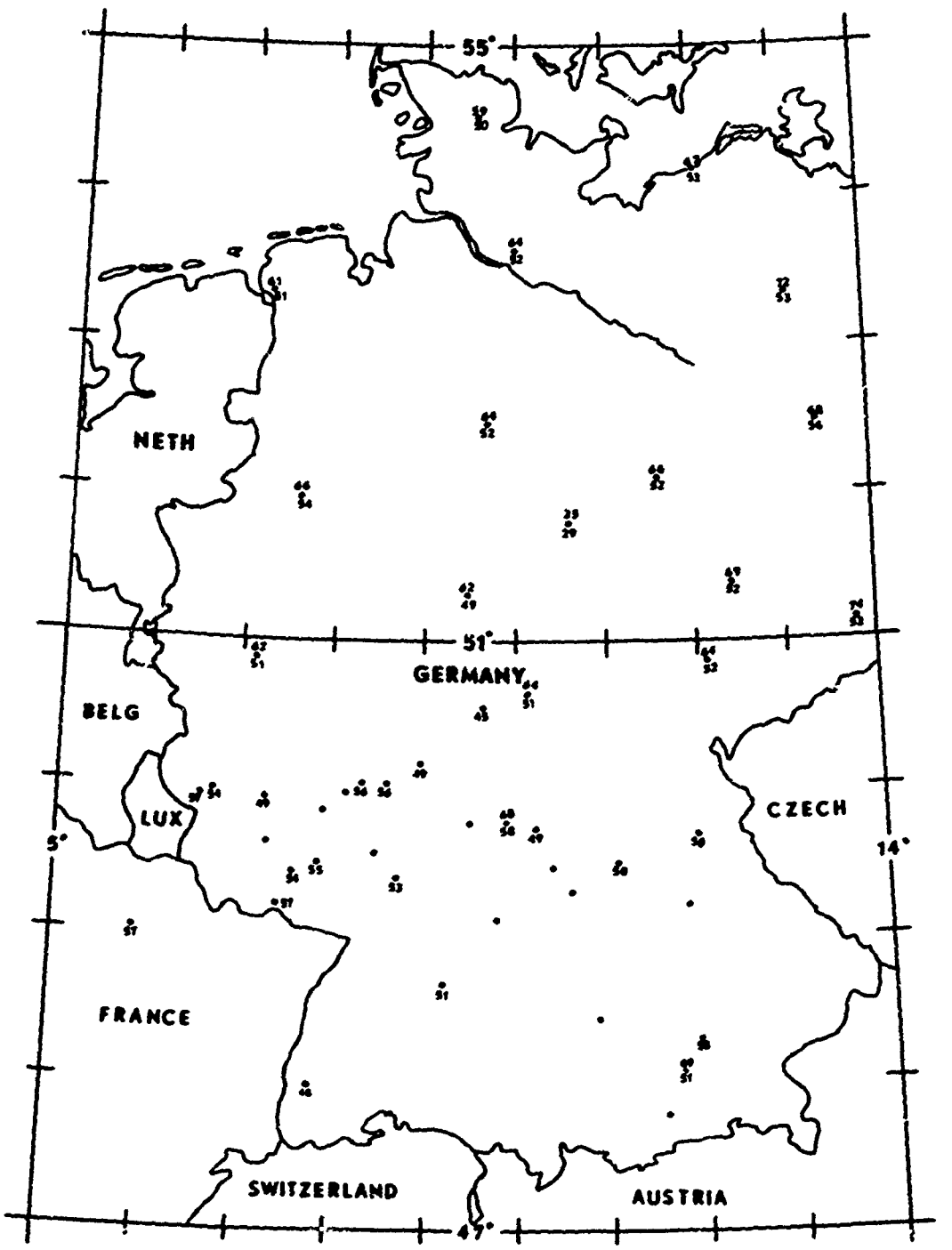

Figure 19. CFLOS Probabilities for Apr, 00-02 LST, 50° Elevation

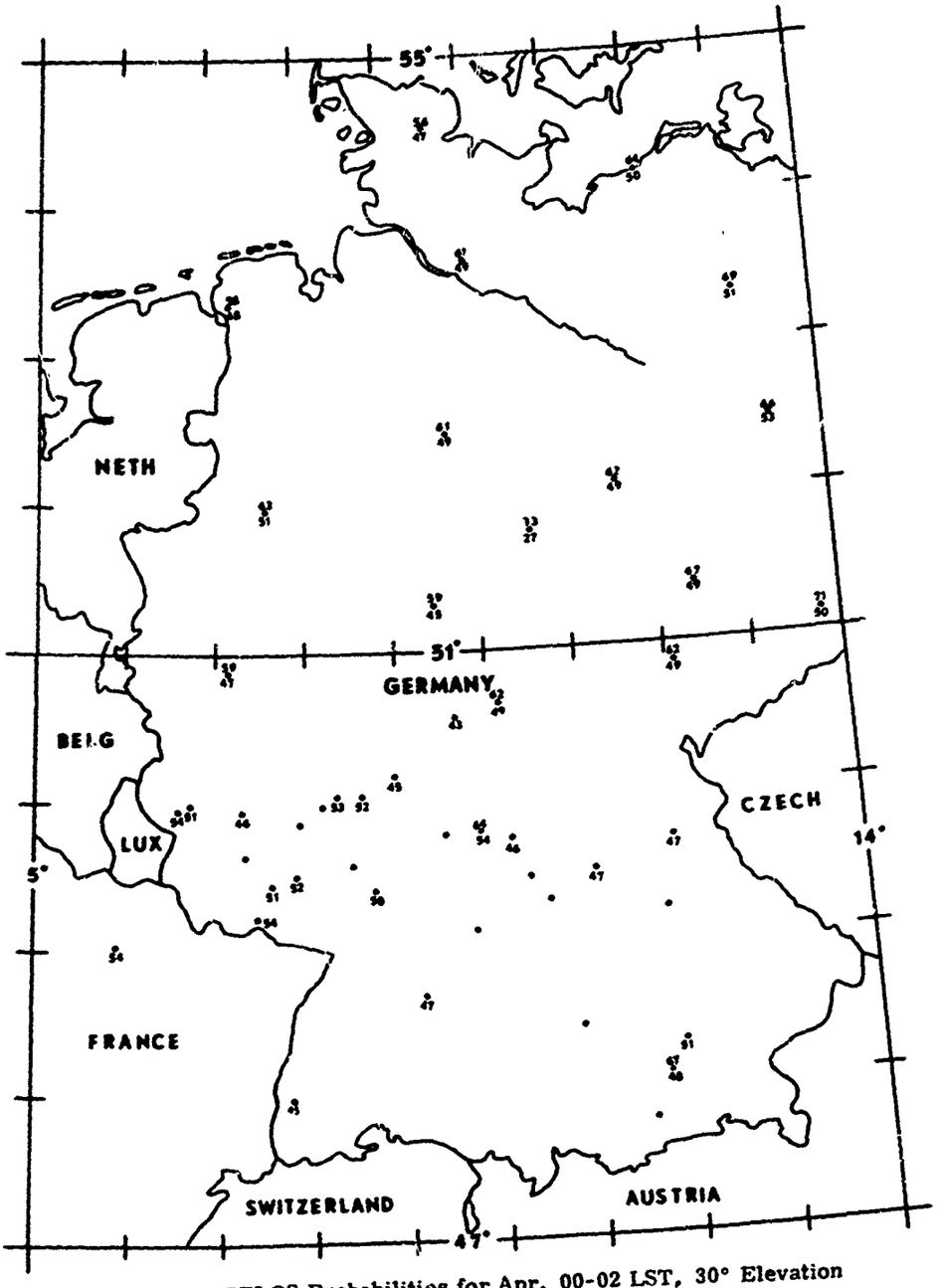

Figure 20. CFLOS Probabilities for Apr, 00-02 LST, 30° Elevation

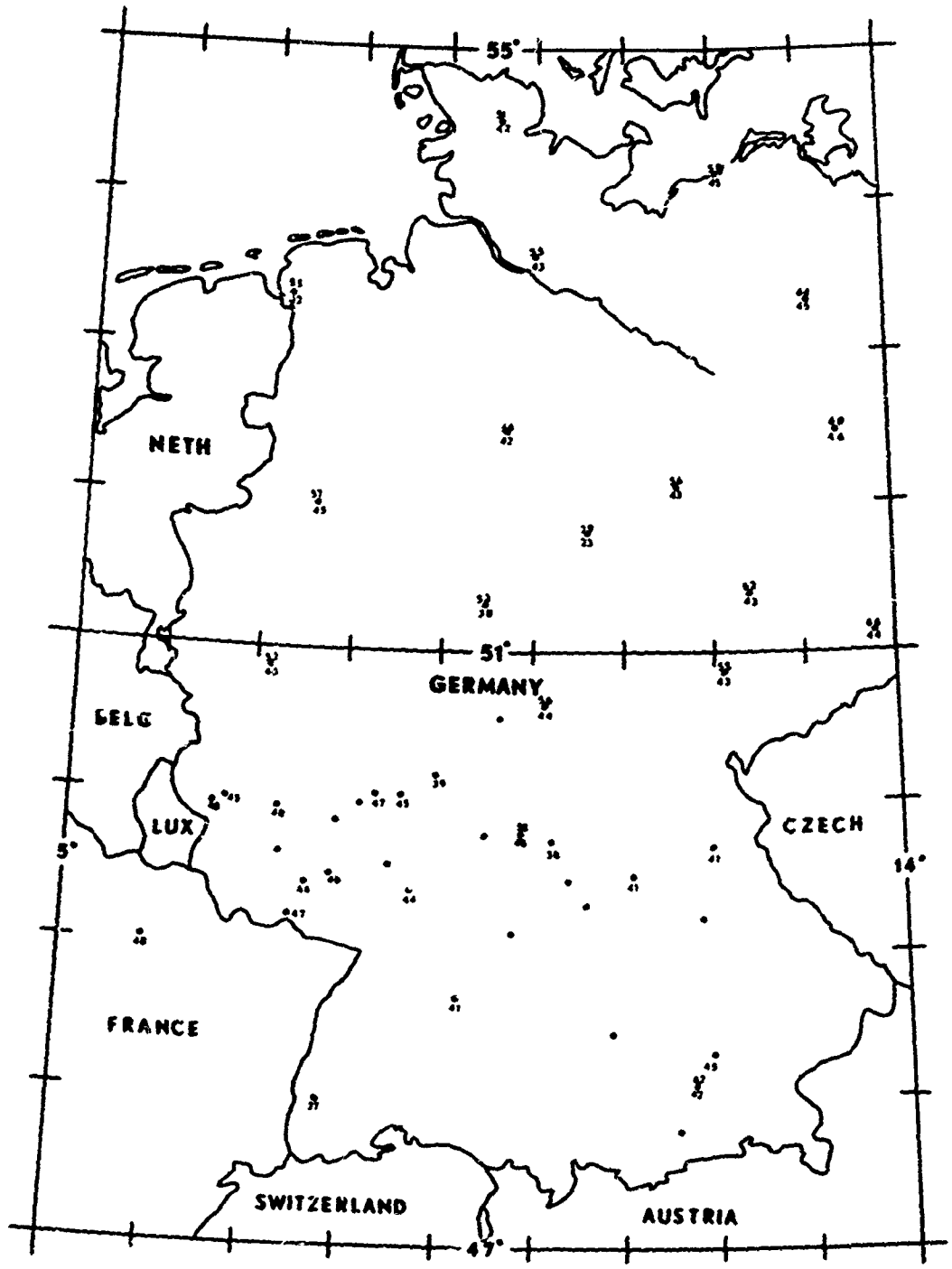

Figure 21. CFLOS Probabilities for Apr, 00-02 LST, 10° Elevation

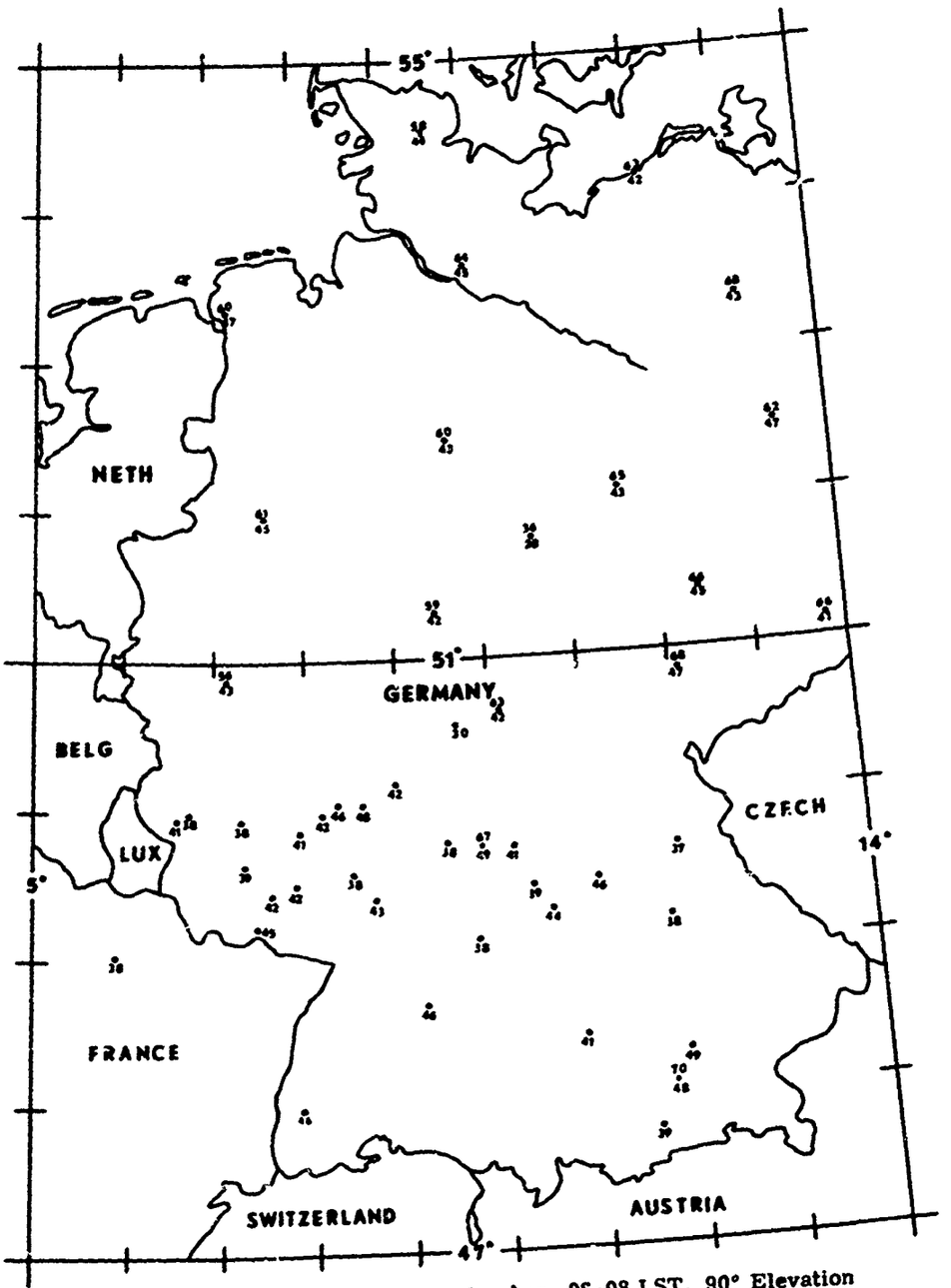

Figure 22. CFLOS Probabilities for Apr, 06-08 LST, 90° Elevation

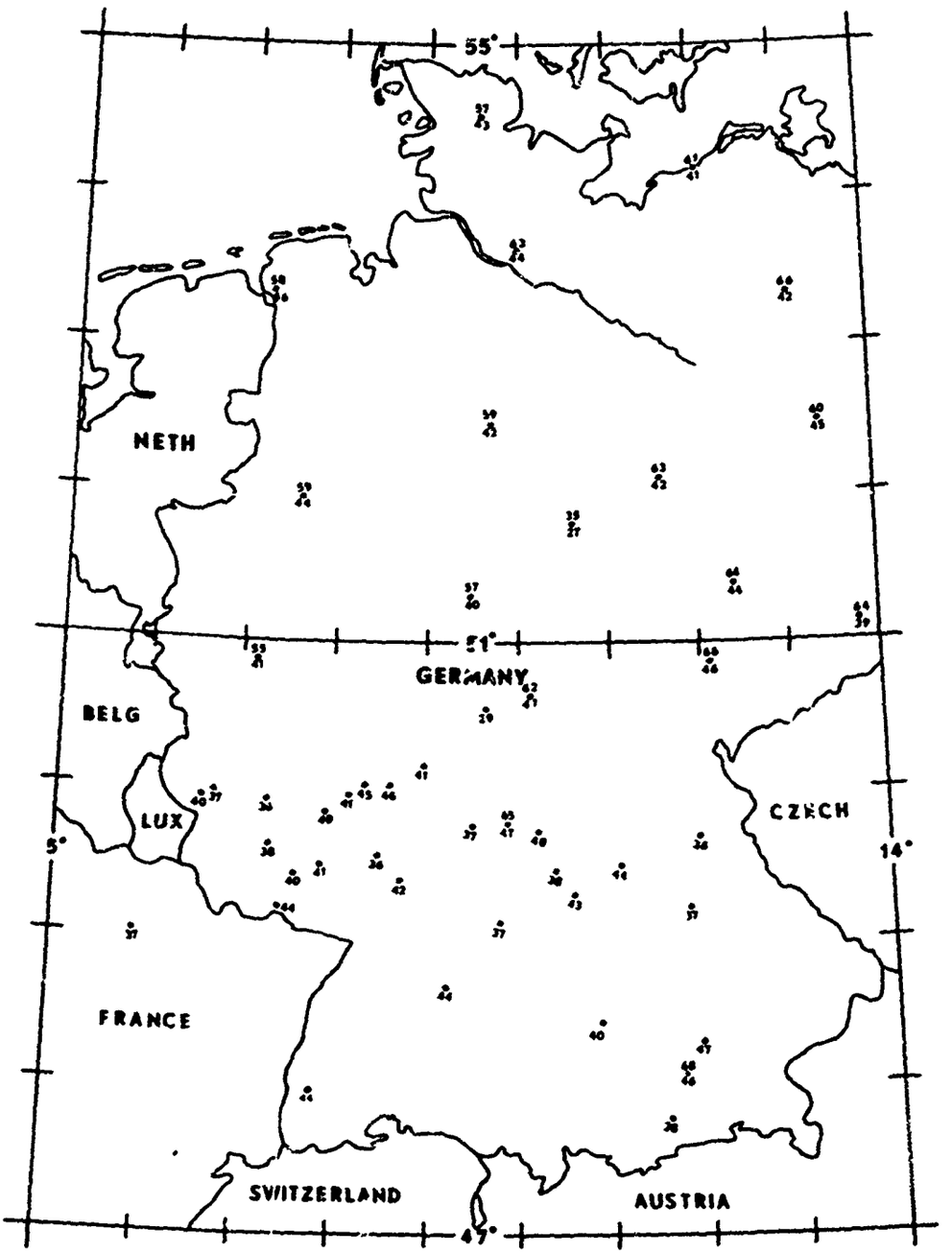

Figure 23. CFLOS Probabilities for Apr, 06-08 LST, 50° Elevation

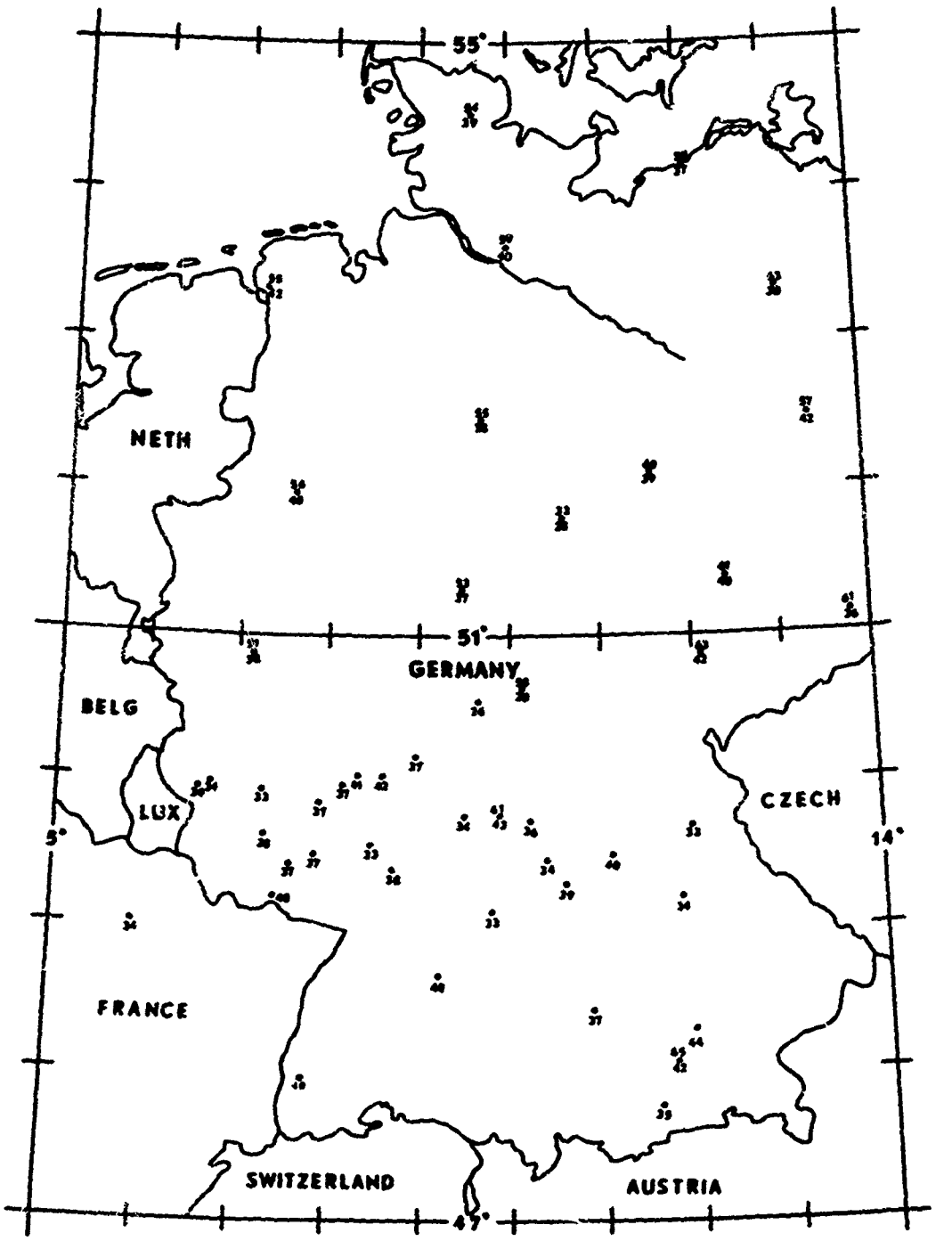

Figure 24. CFLOS Probabilities for Apr, 06-08 LST, 30° Elevation

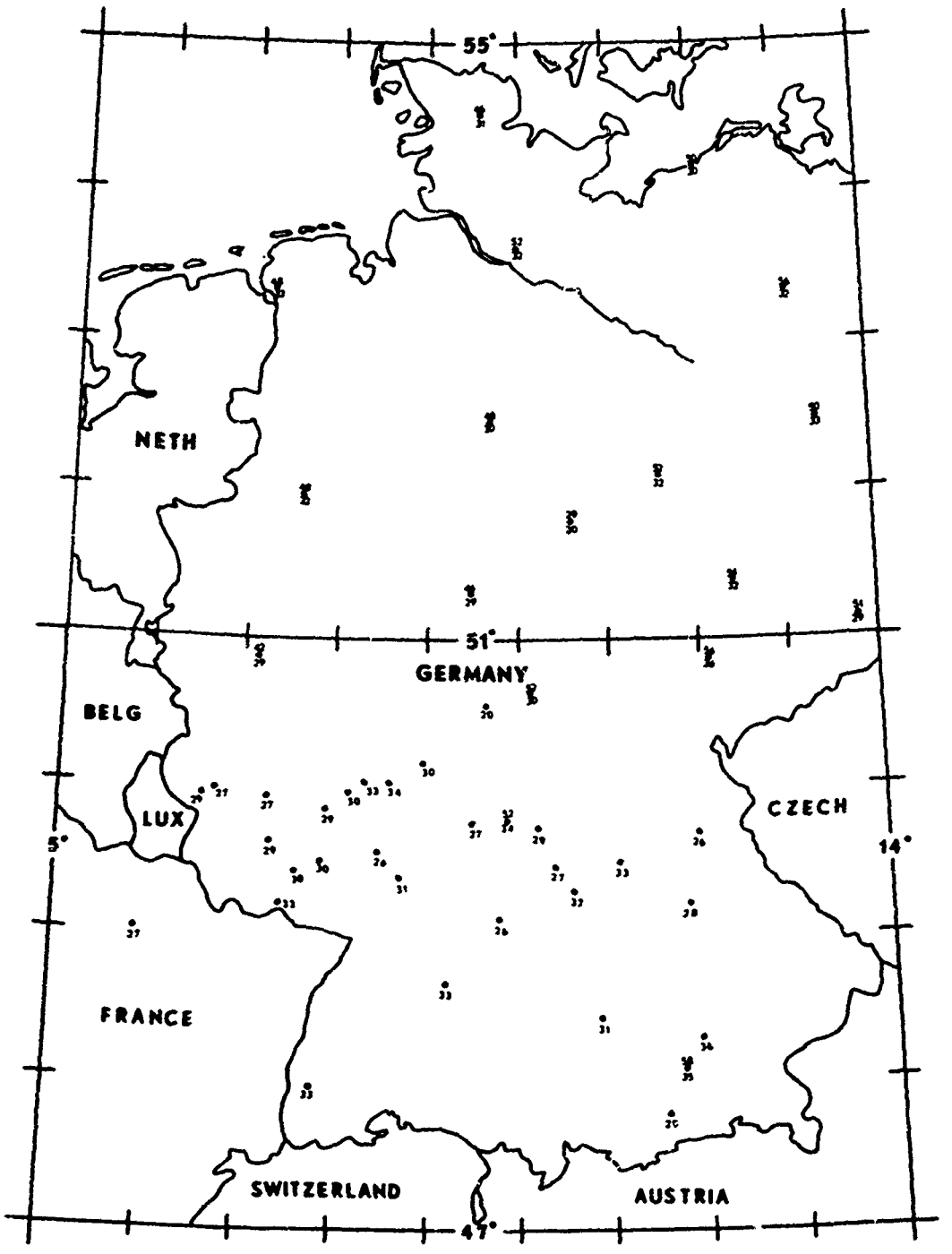

Figure 25. CFLOS Probabilities for Apr, 06-08 LST, 10° Elevation

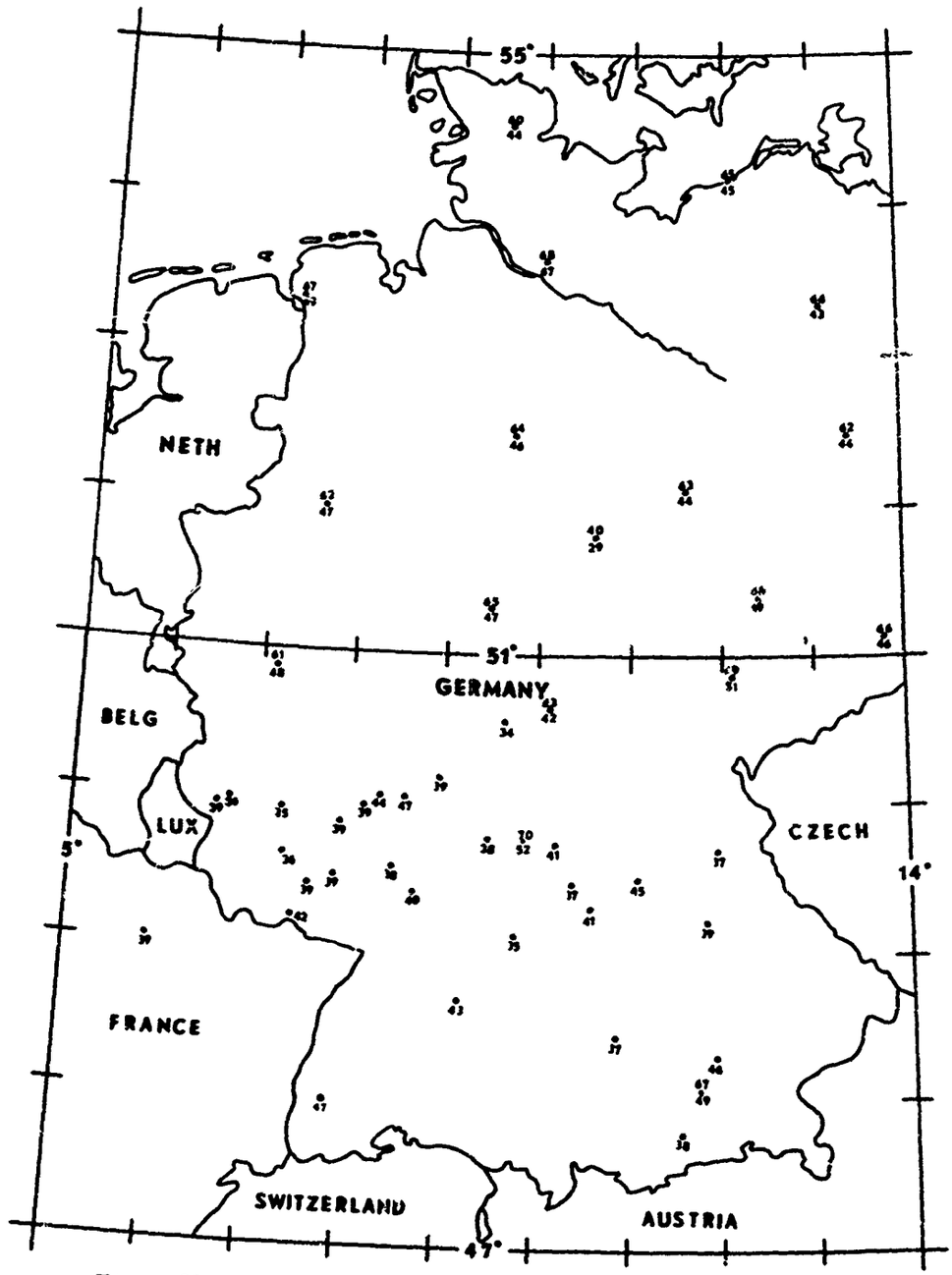

Figure 26. CFLOS Probabilities for Apr, 12-14 LST, 90° Elevation

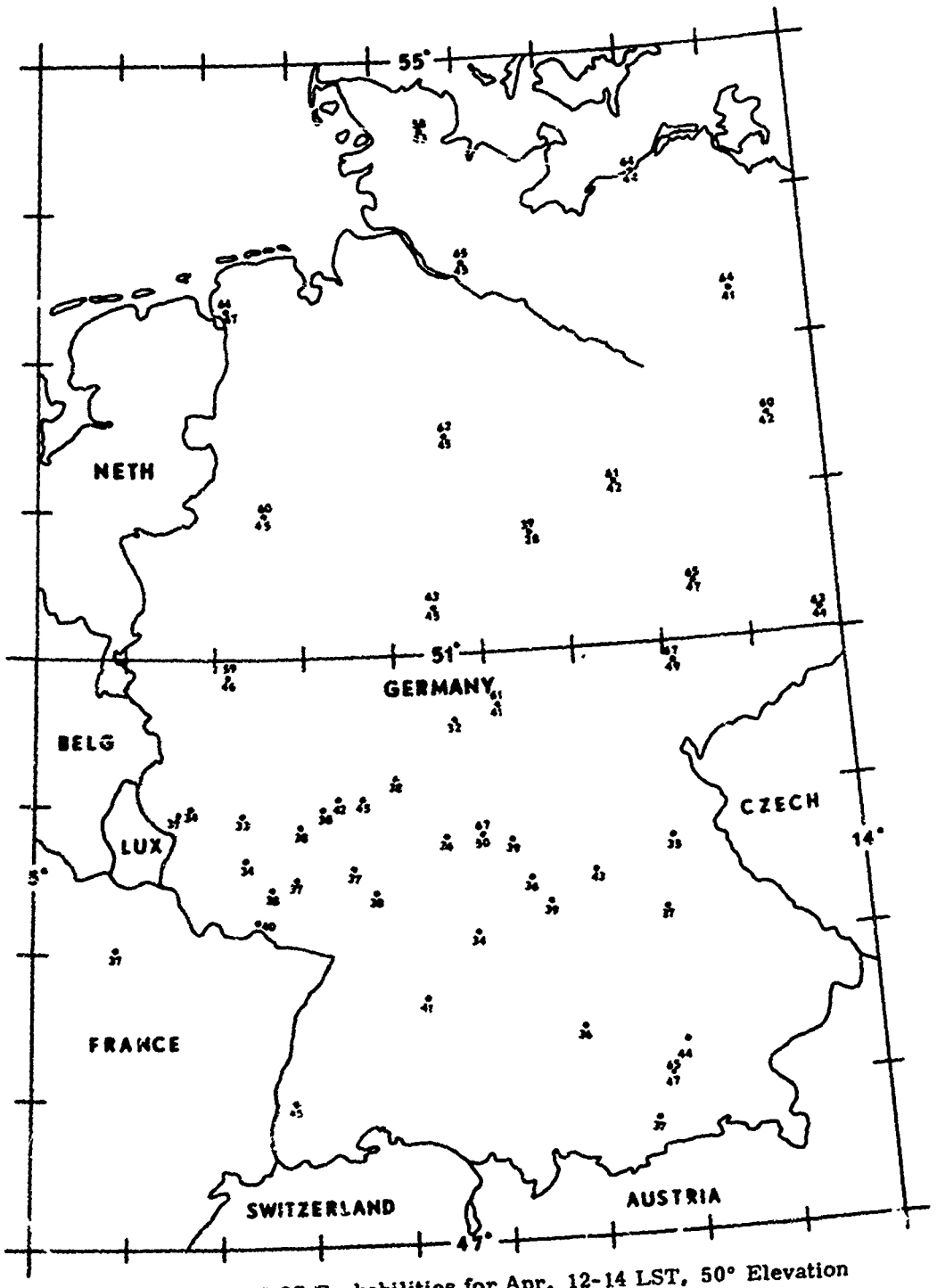

Figure 27. CFLOS Probabilities for Apr, 12-14 LST, 50° Elevation

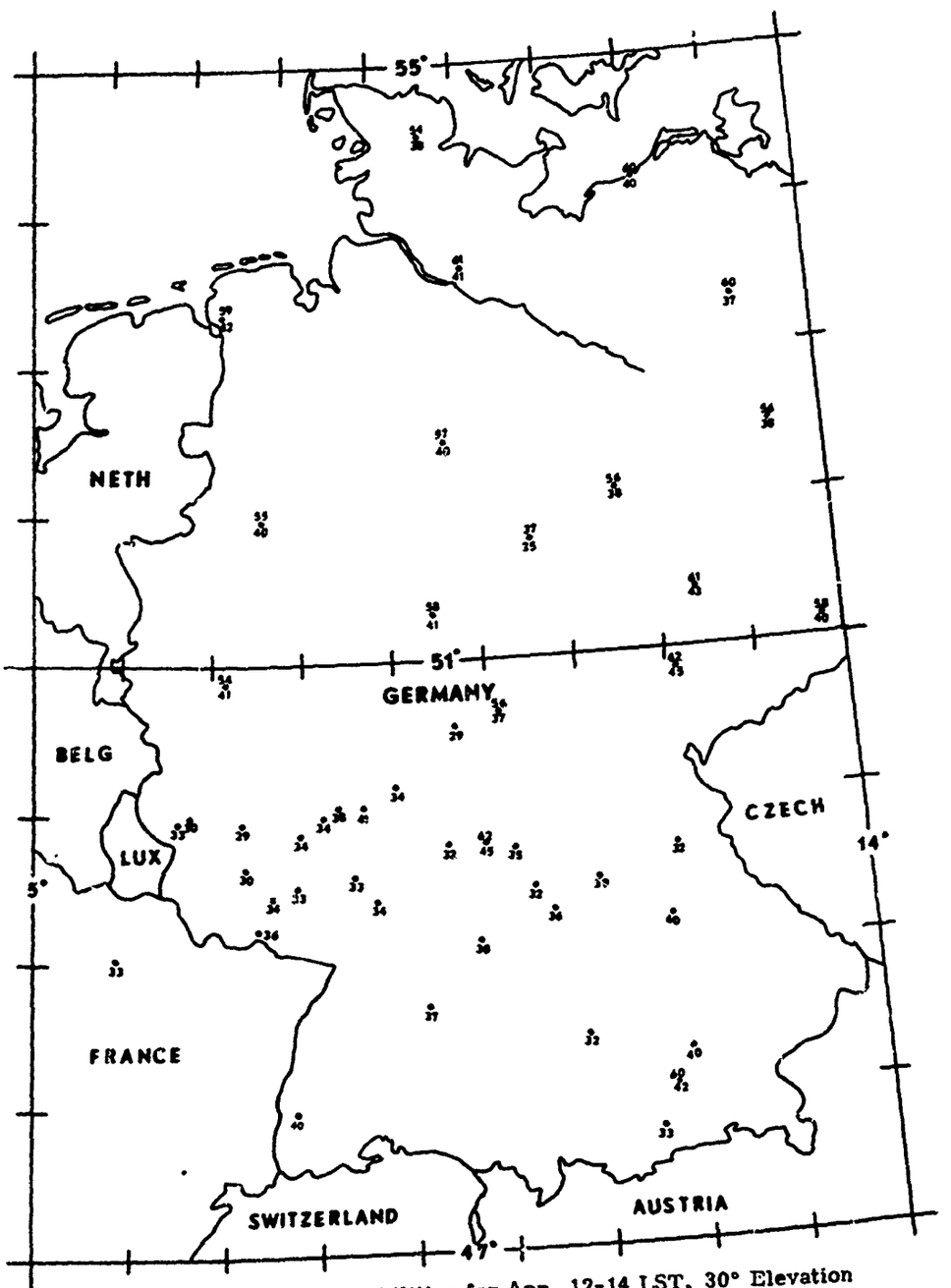

Figure 28. CFLOS Probabilities for Apr, 12-14 LST, 30° Elevation

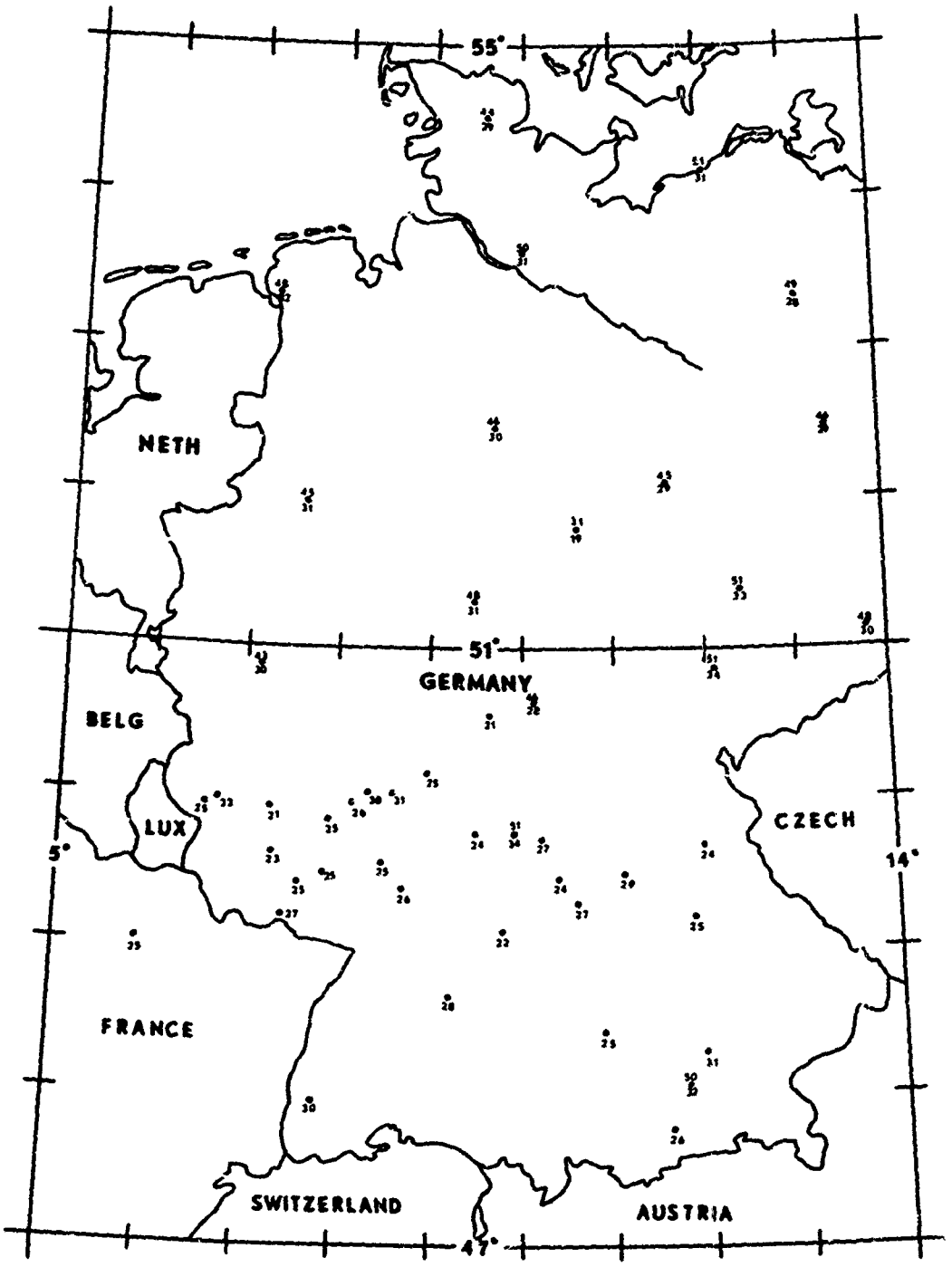

Figure 29. CFLOS Probabilities for Apr, 12-14 LST, 10° Elevation

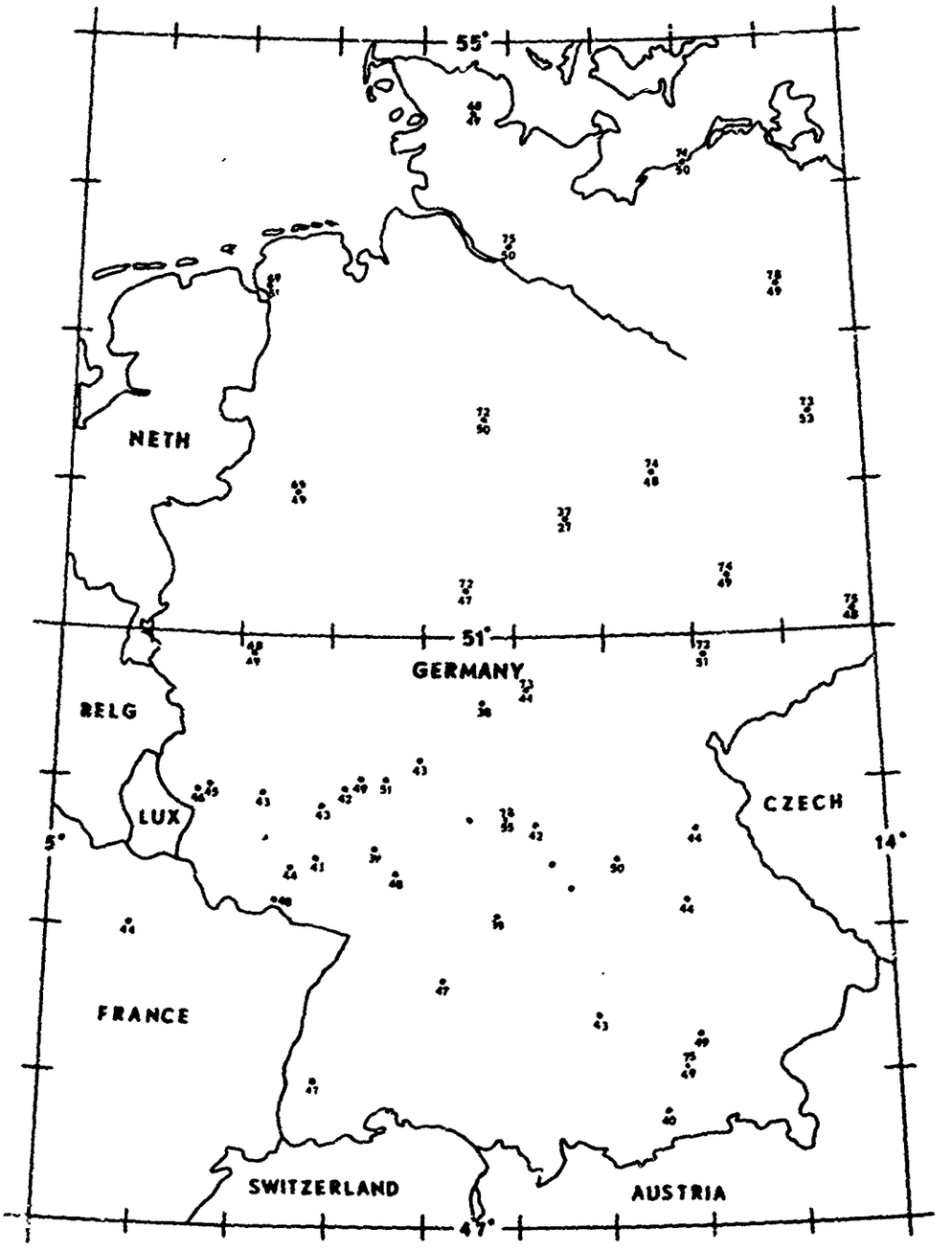

Figure 30. CFLOS Probabilities for Apr, 18-20 LST, 90° Elevation

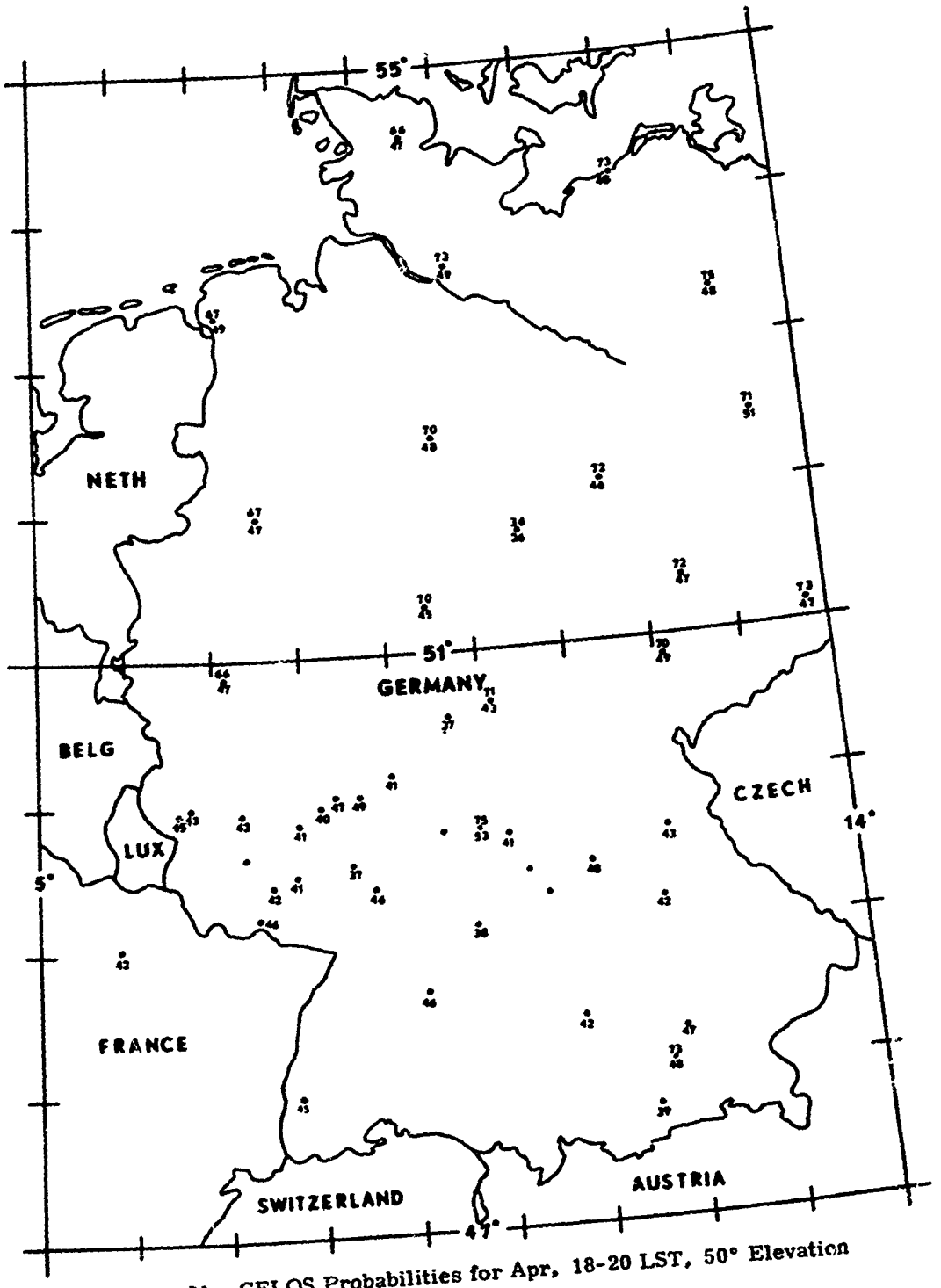

Figure 31. CFLOS Probabilities for Apr, 18-20 LST, 50° Elevation

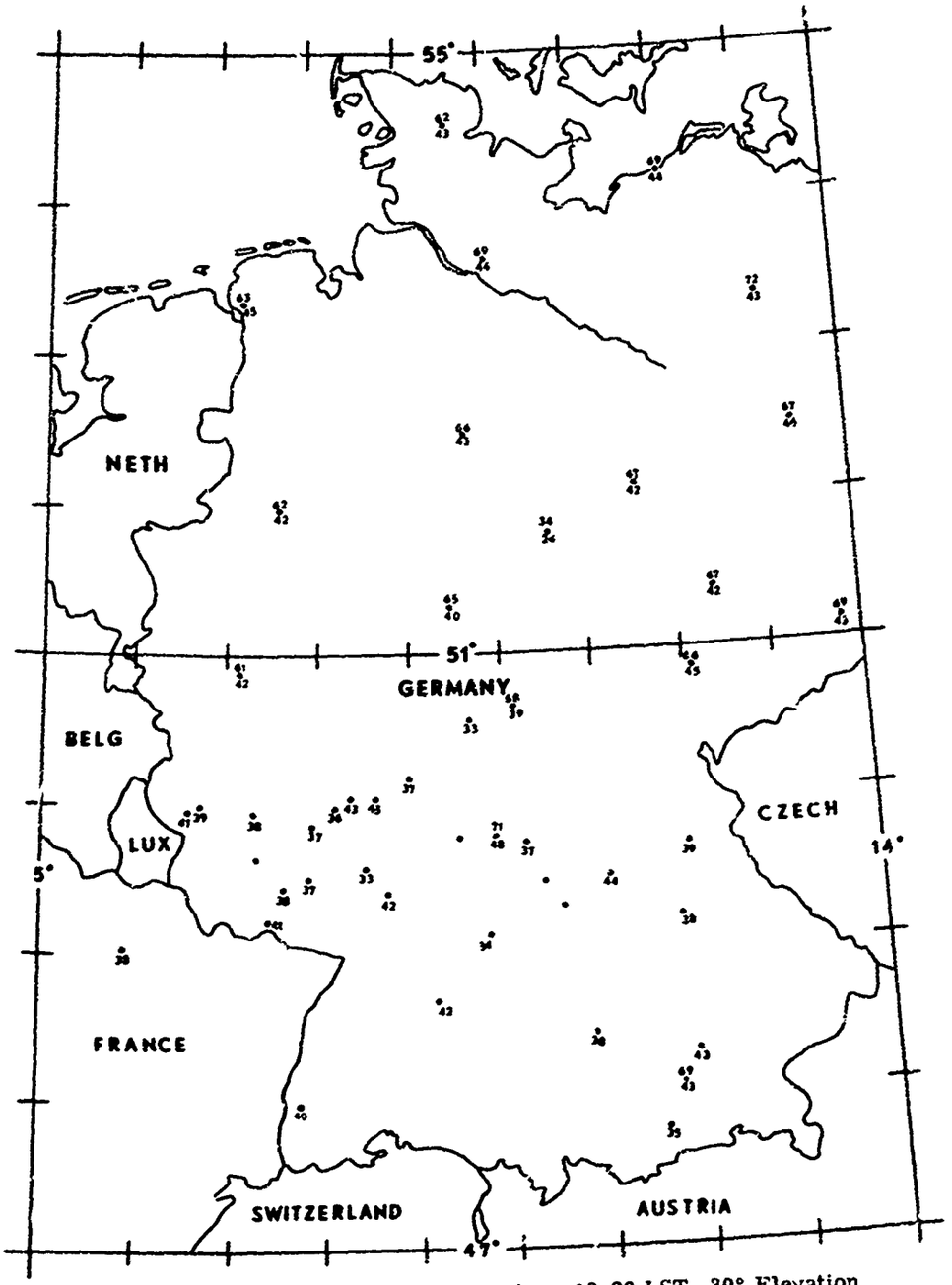

Figure 32. CFLOS Probabilities for Apr, 18-20 LST, 30° Elevation

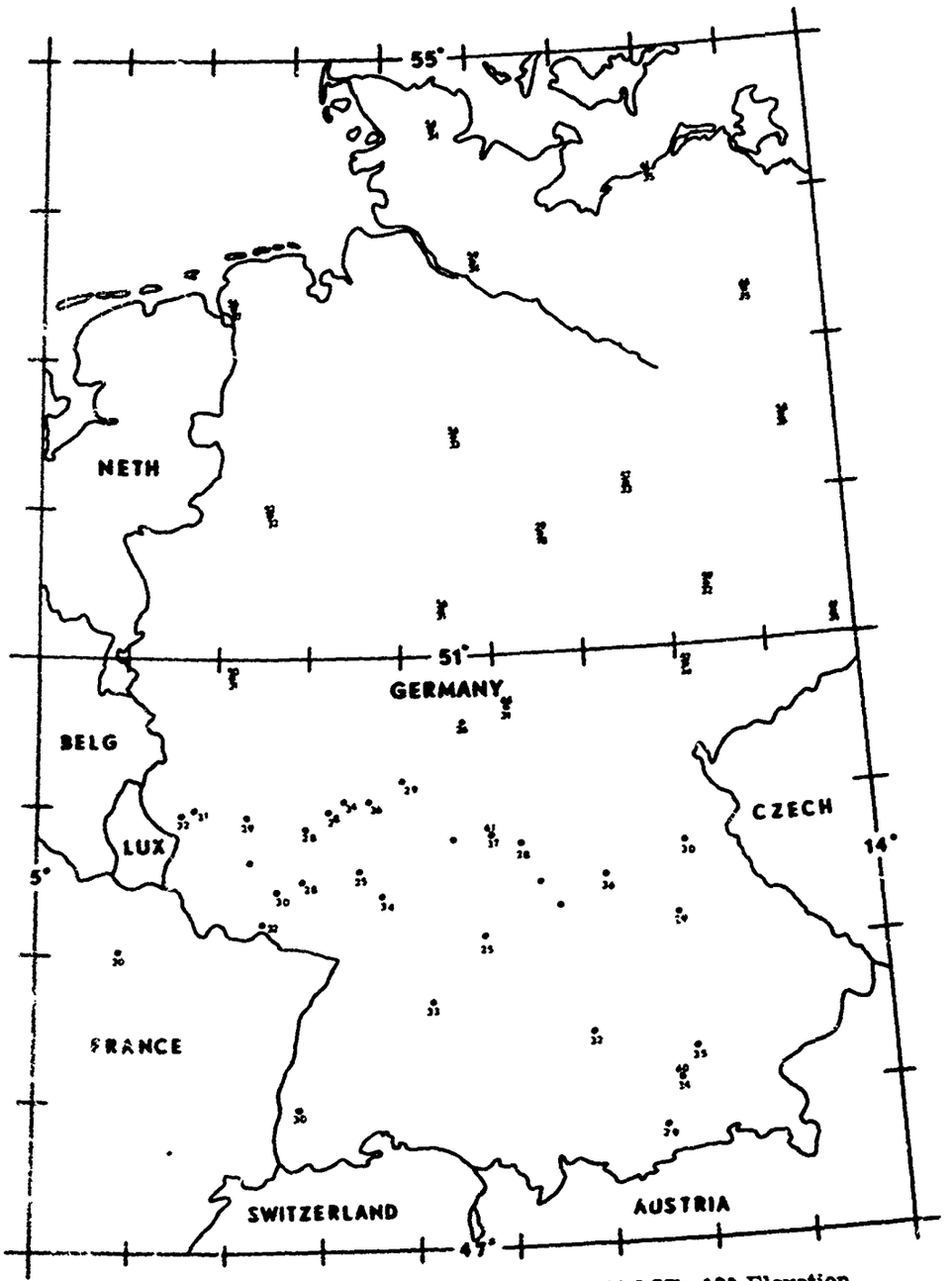

Figure 32. CFLOS Probabilities for Apr, 18-20 LST, 10° Elevation

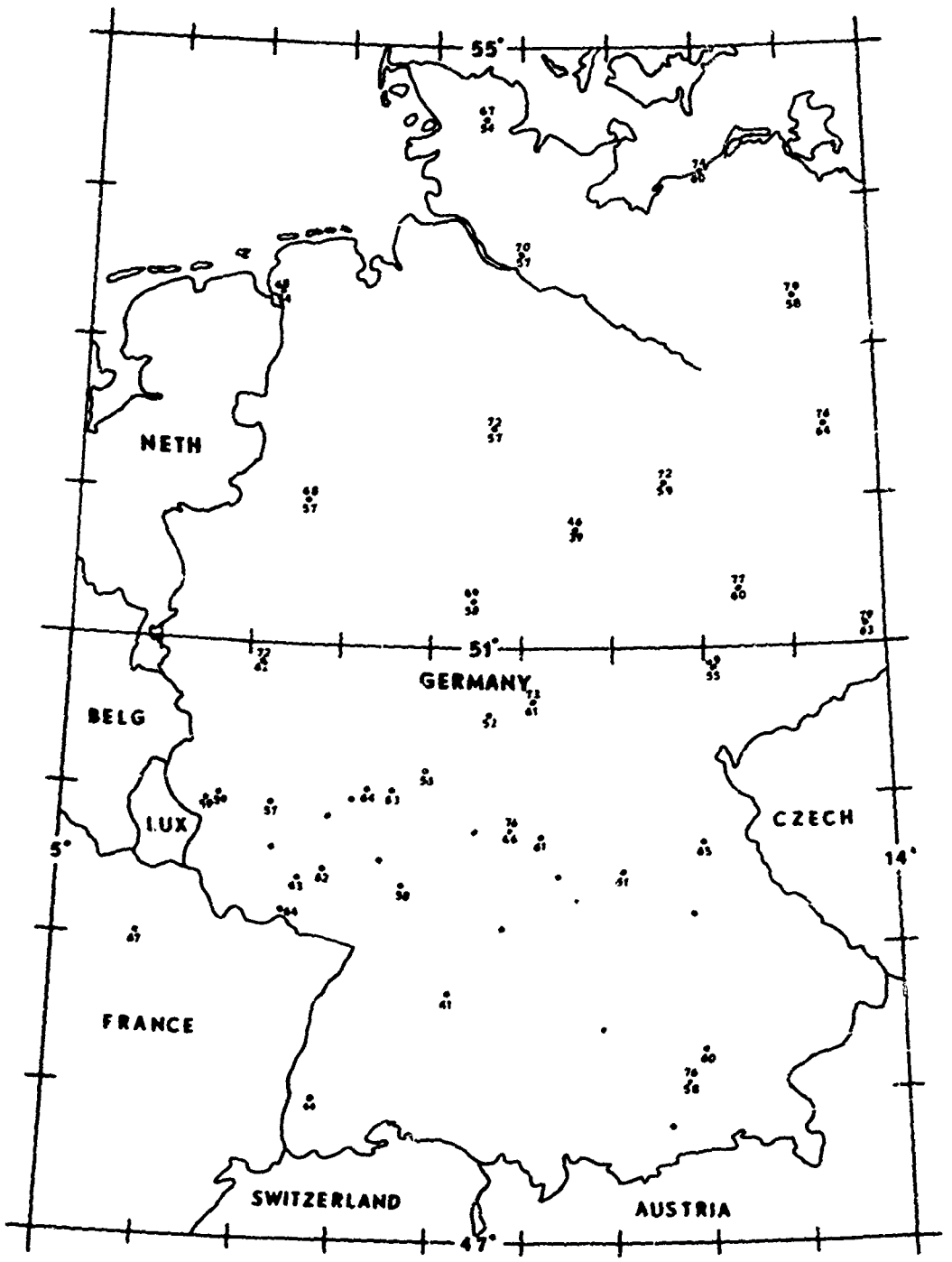

Figure 34. CFLOS Probabilities for Jul, 00-02 LST, 90° Elevatio

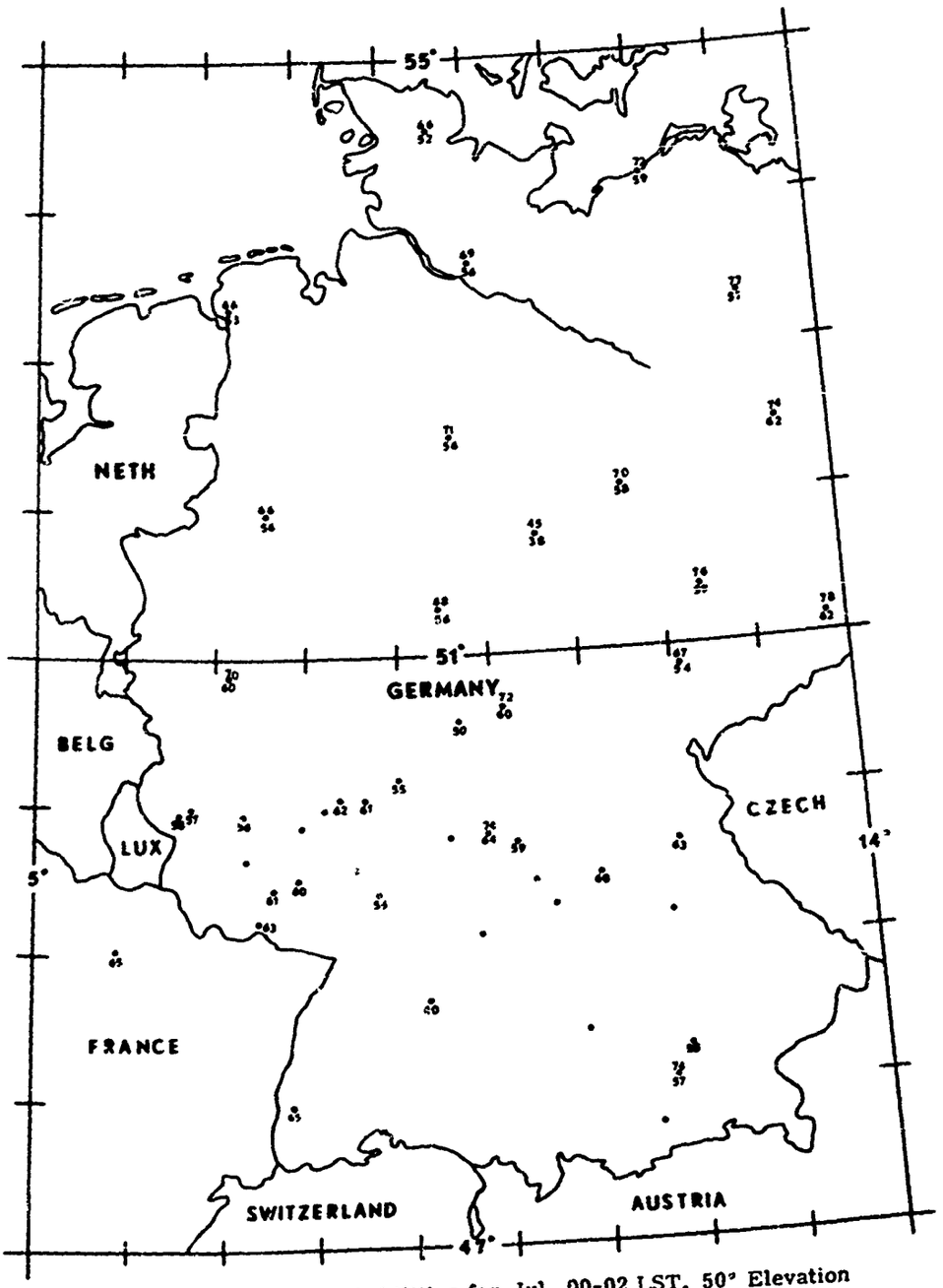

Figure 35. CFLOS Probabilities for Jul, 00-02 LST, 50° Elevation

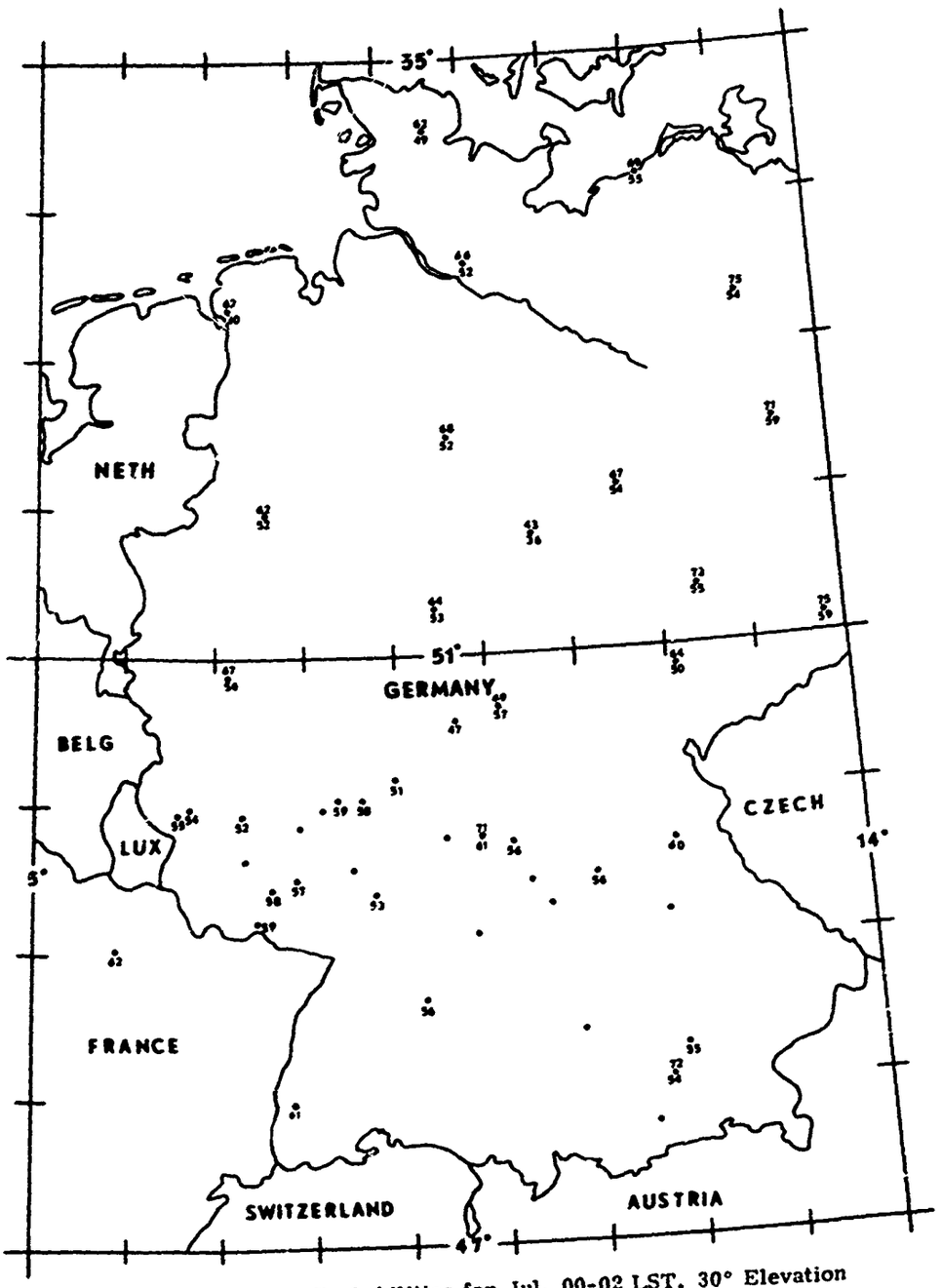

Figure 36. CFLOS Probabilities for Jul, 00-02 LST, 30° Elevation

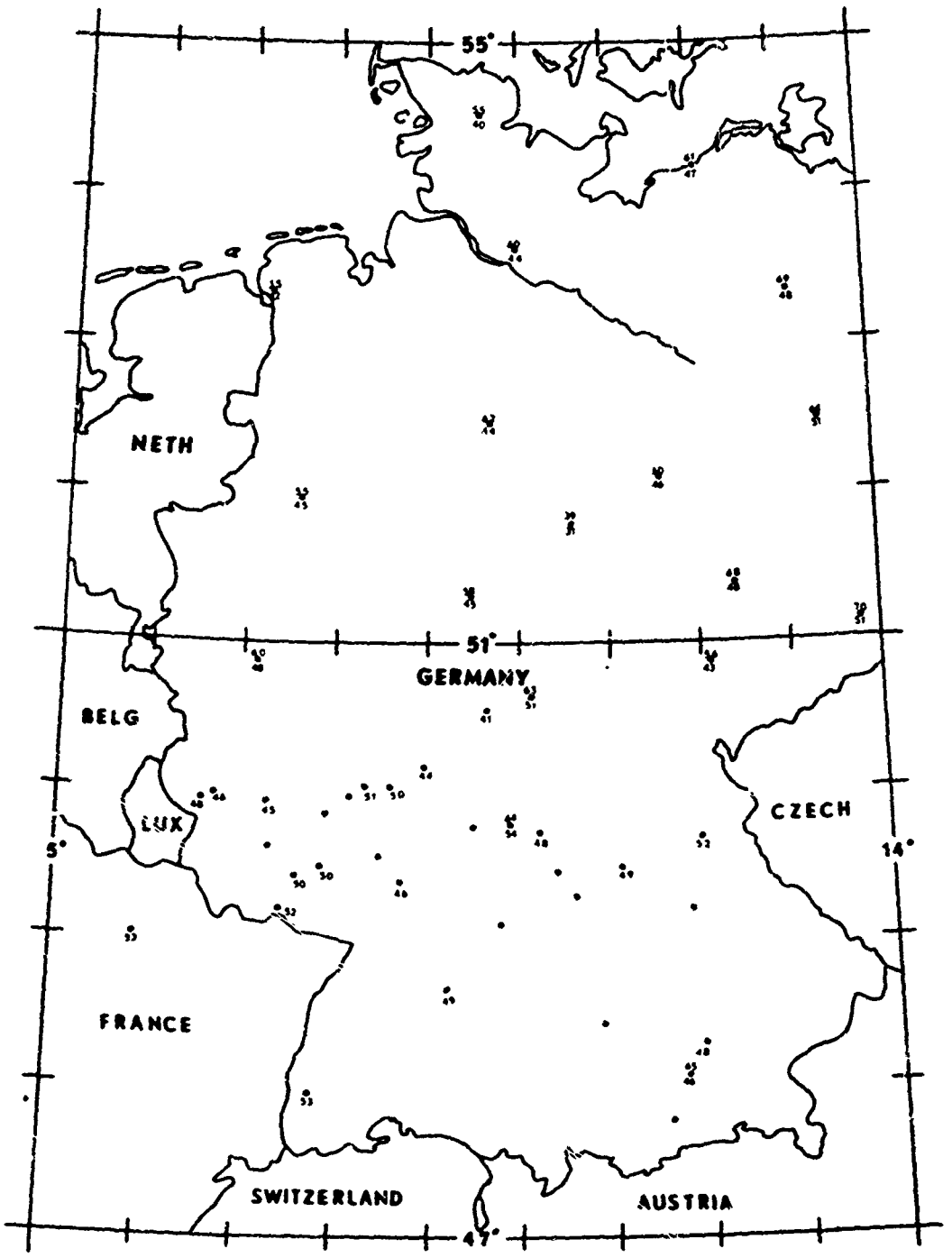

Figure 37. CFLOS Probabilities for Jul, 00-02 LST, 10° Elevation

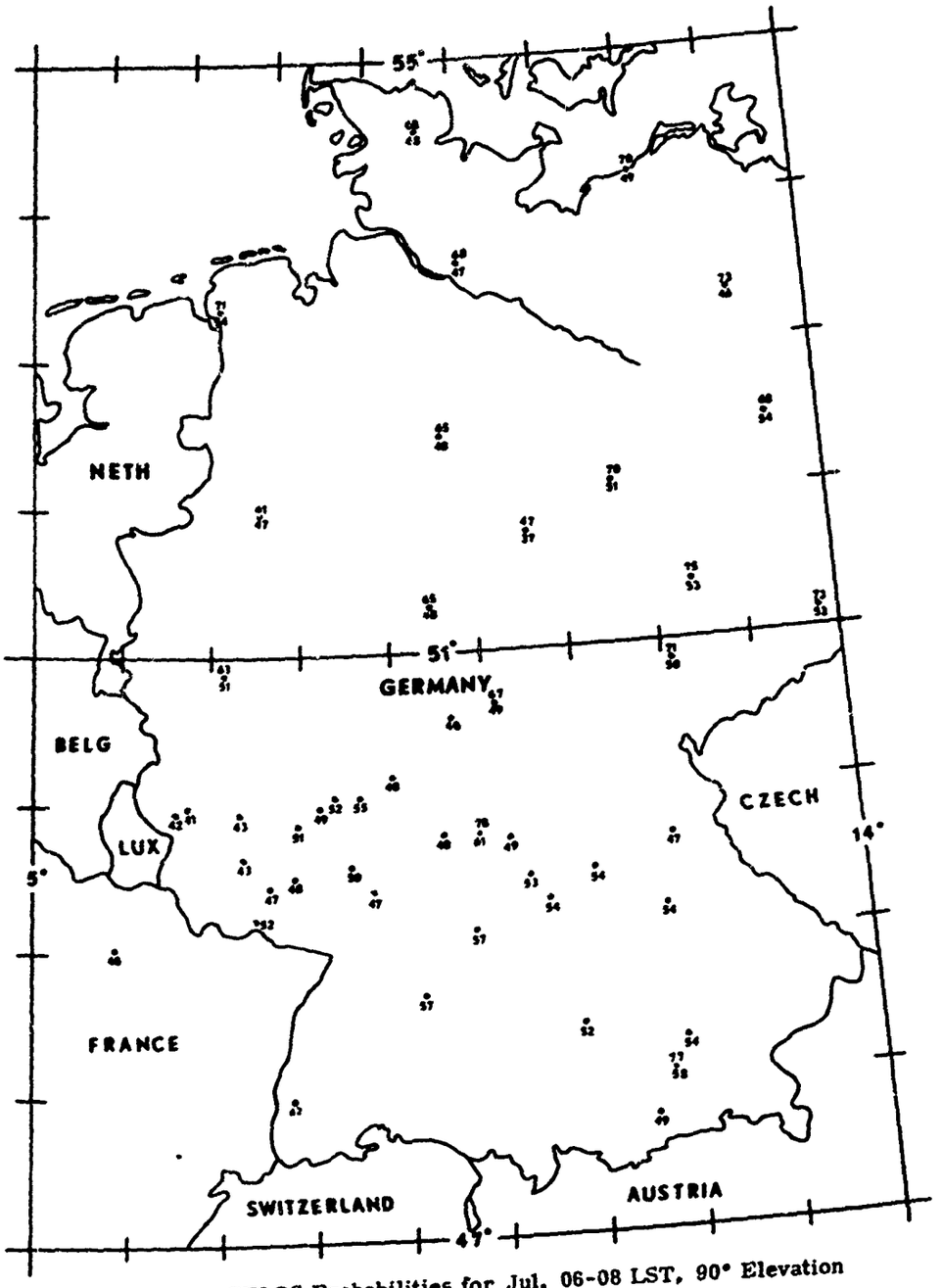

Figure 38. CFLOS Probabilities for Jul, 06-08 LST, 90° Elevation

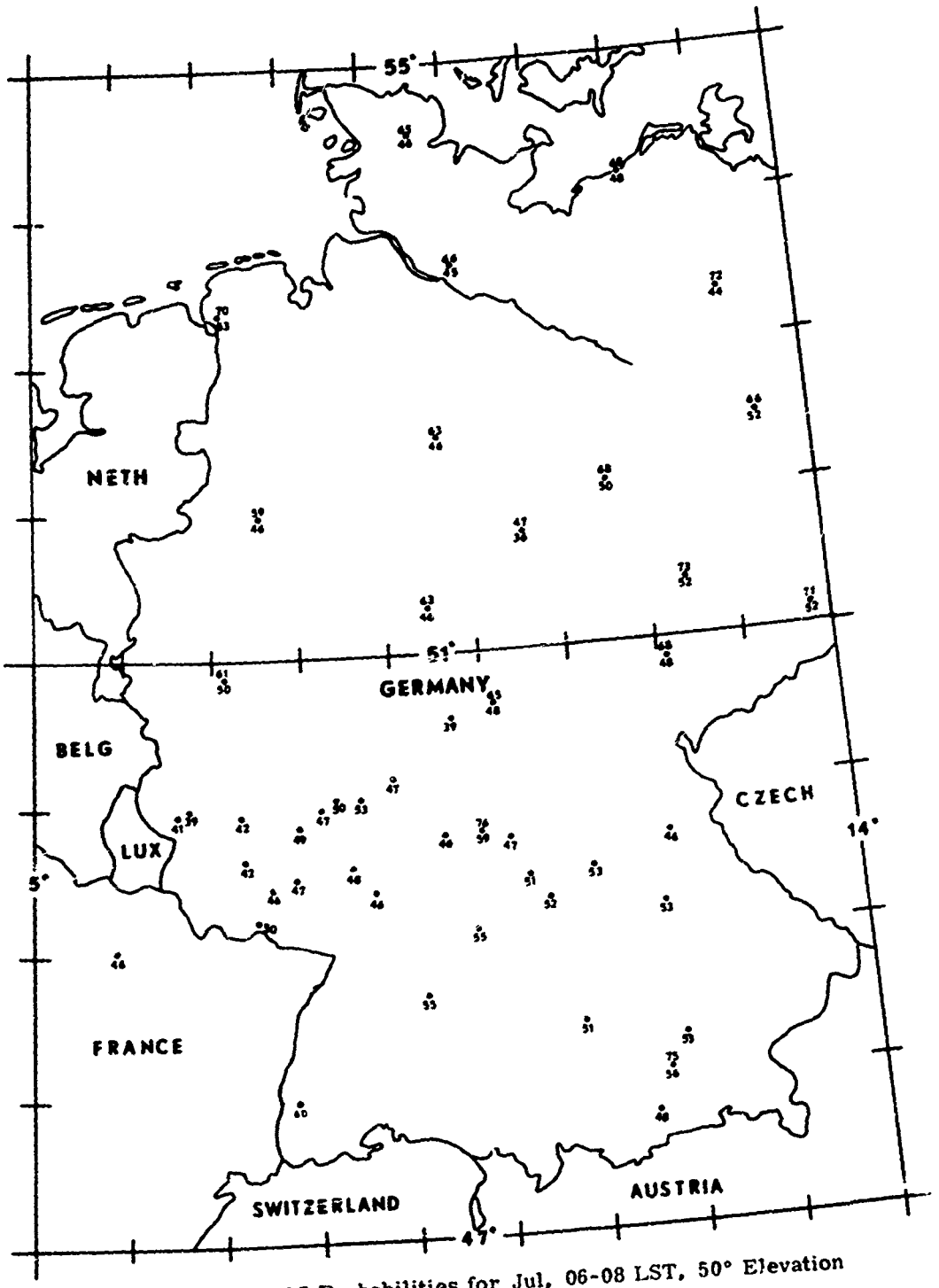

Figure 39. CFLOS Probabilities for Jul, 06-08 LST, 50° Elevation

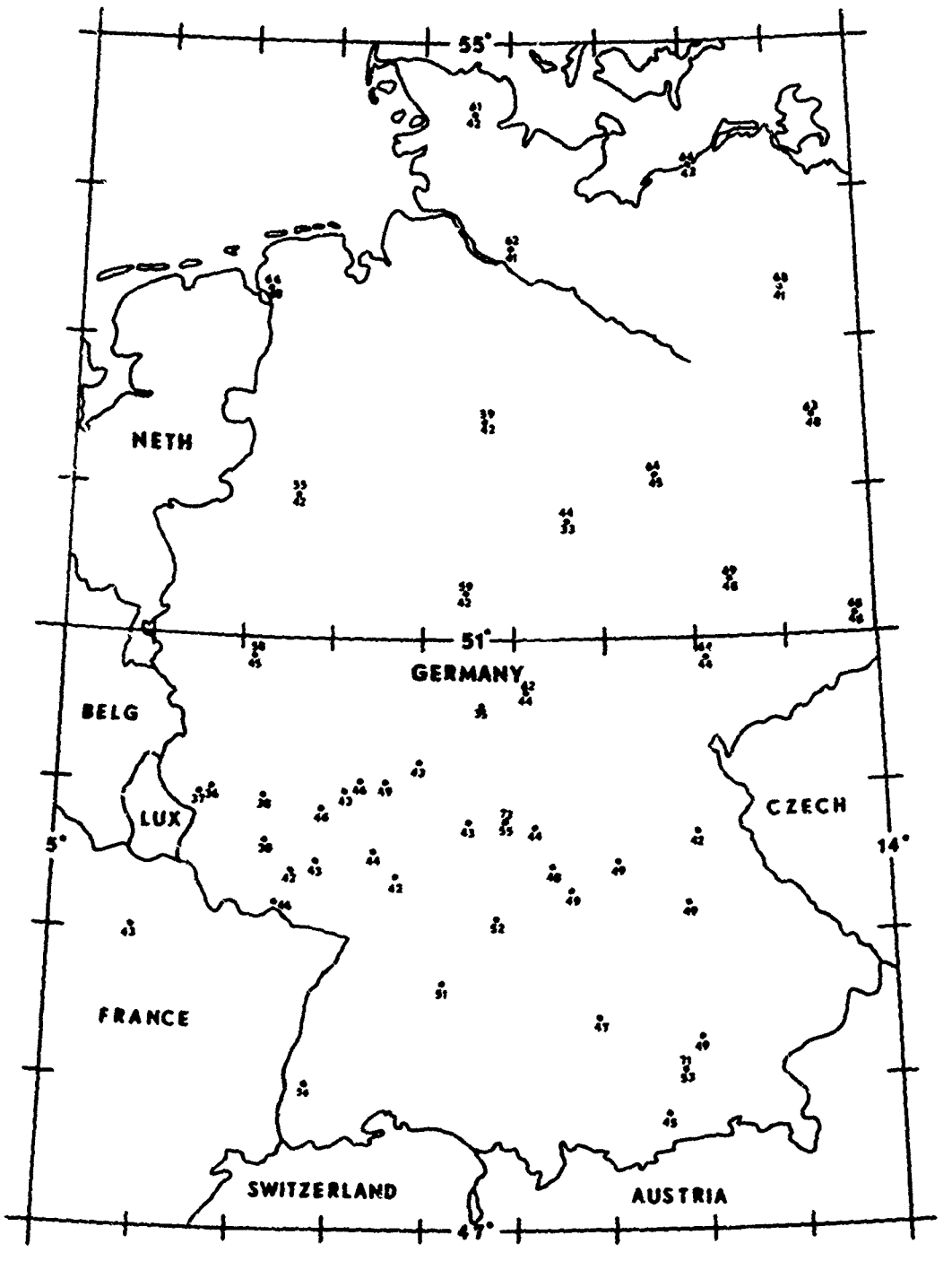

Figure 40. CFLOS Probabilities for Jul, 06-08 LST, 30° Elevation

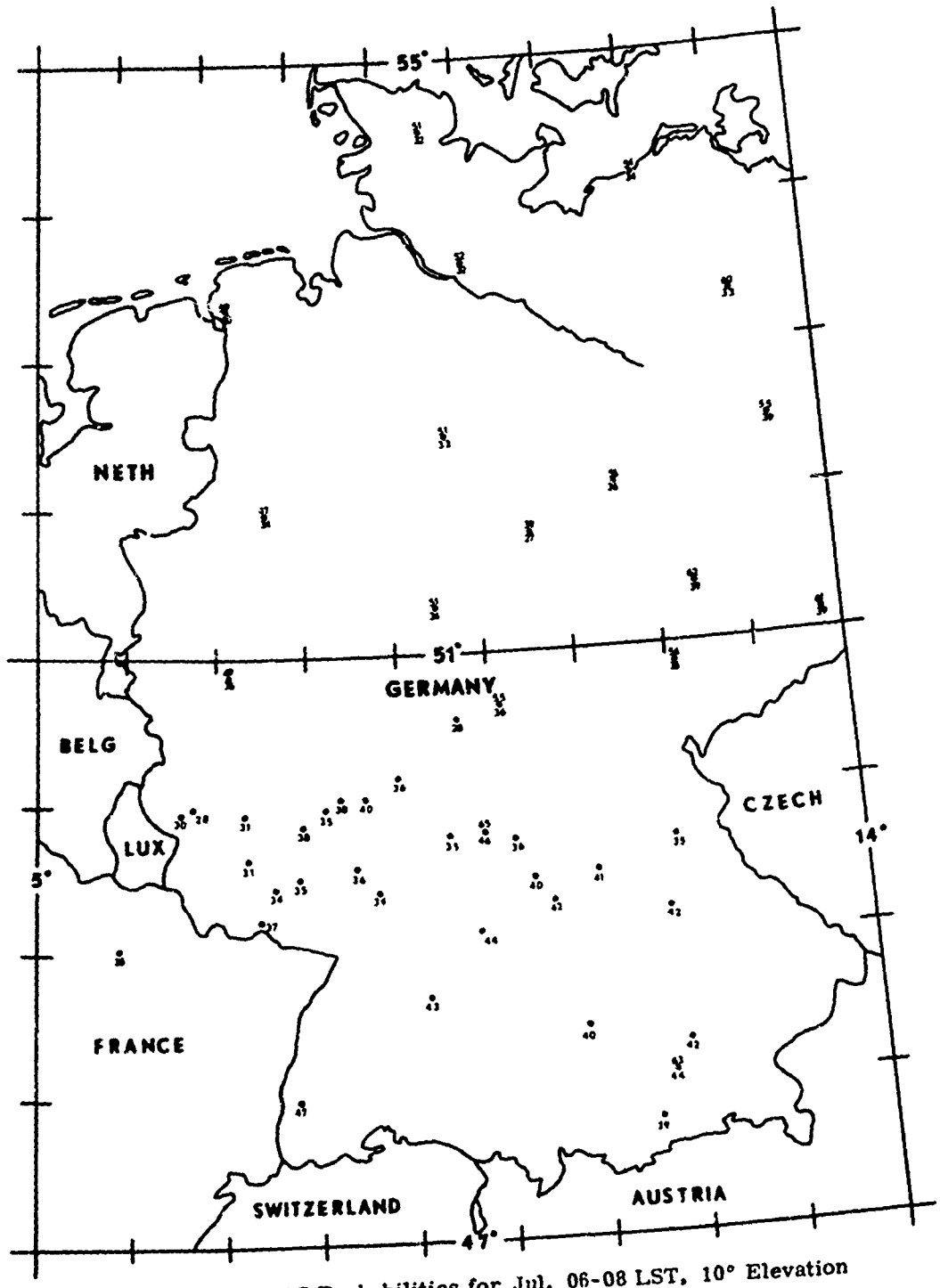

Figure 41. CFLOS Probabilities for Jul, 06-08 LST, 10° Elevation

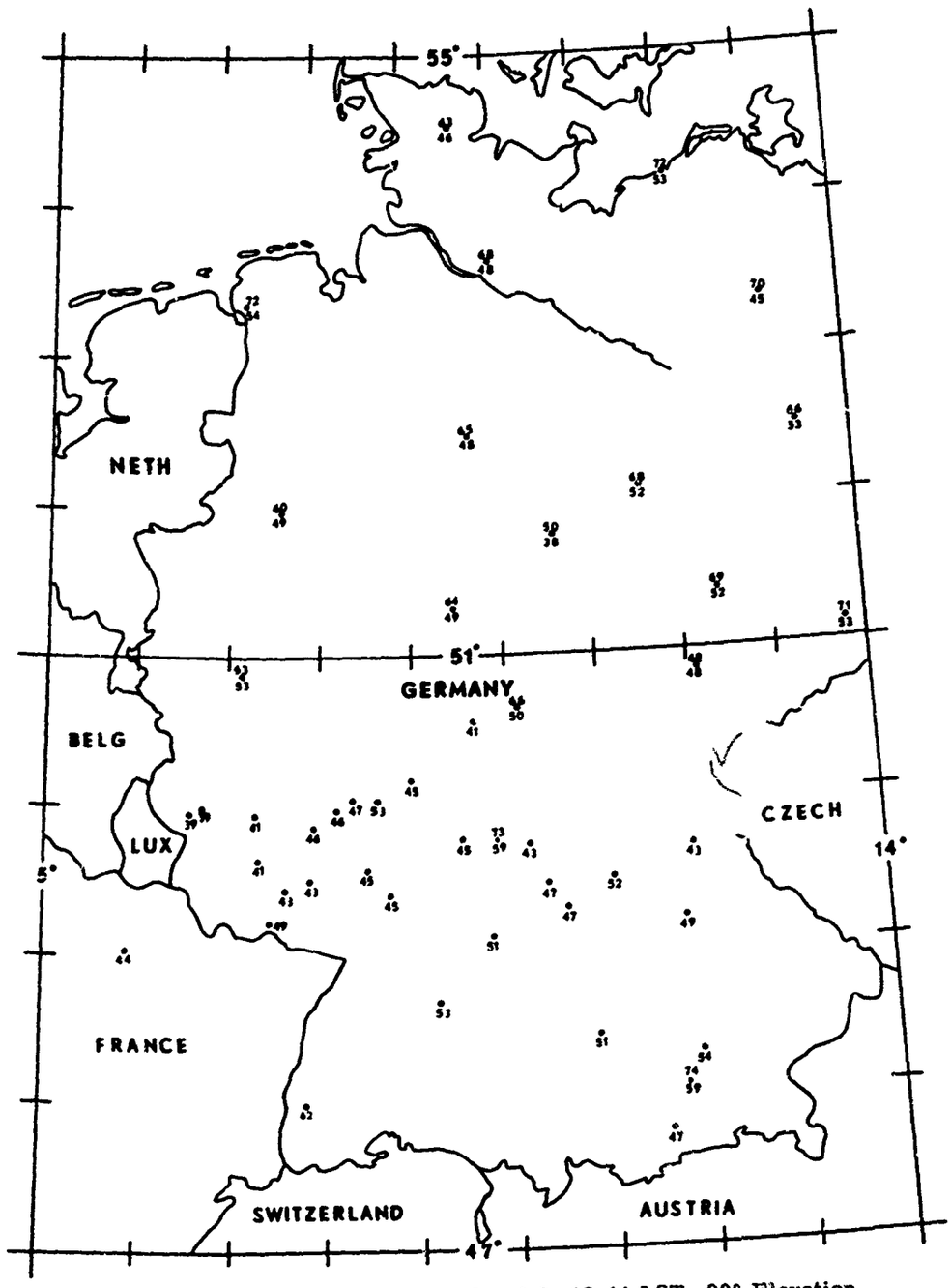

Figure 42. CFLOS Probabilities for Jul, 12-14 LST, 90° Elevation

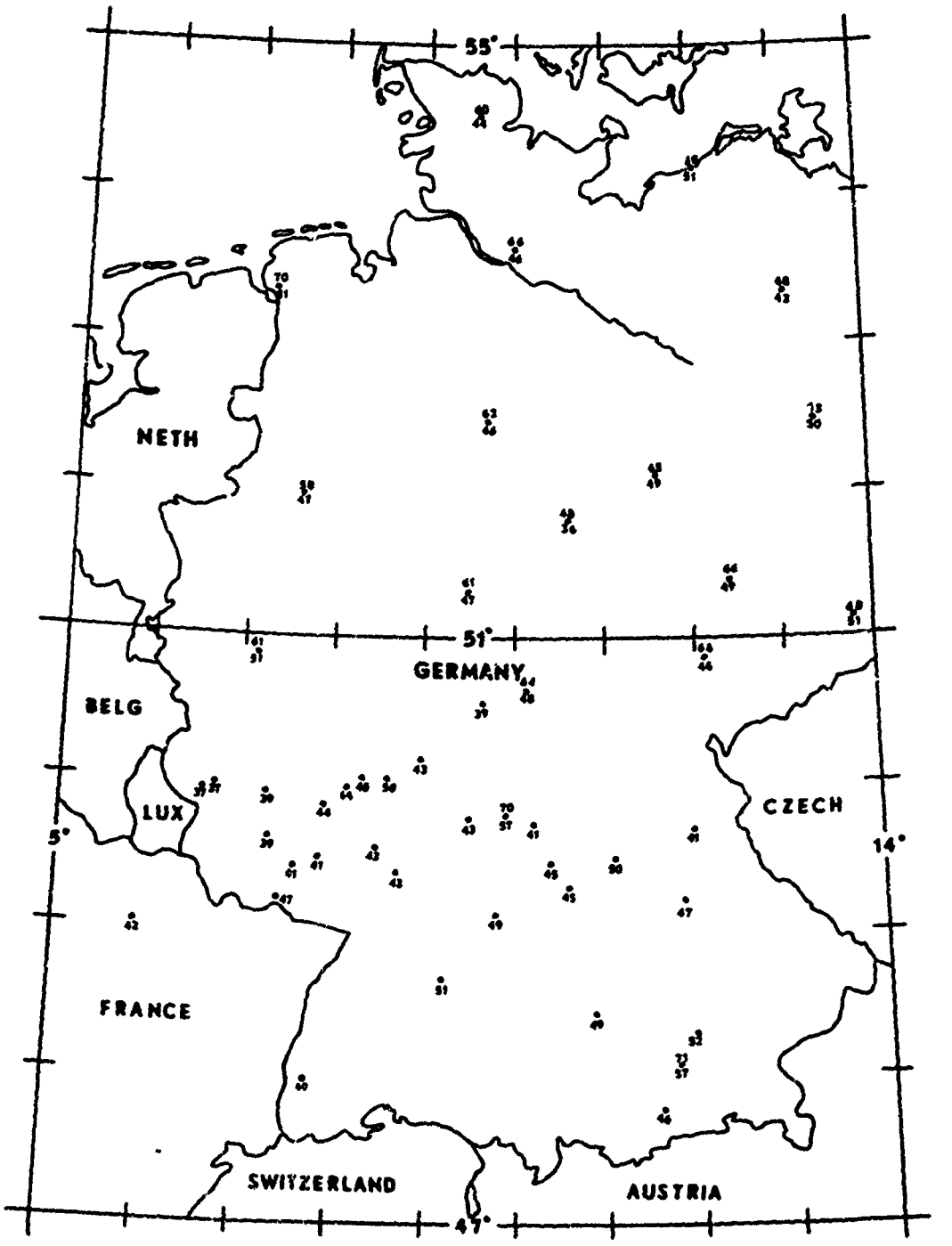

Figure 43. CFLOS Probabilities for Jul, 12-14 LST, 50° Elevation

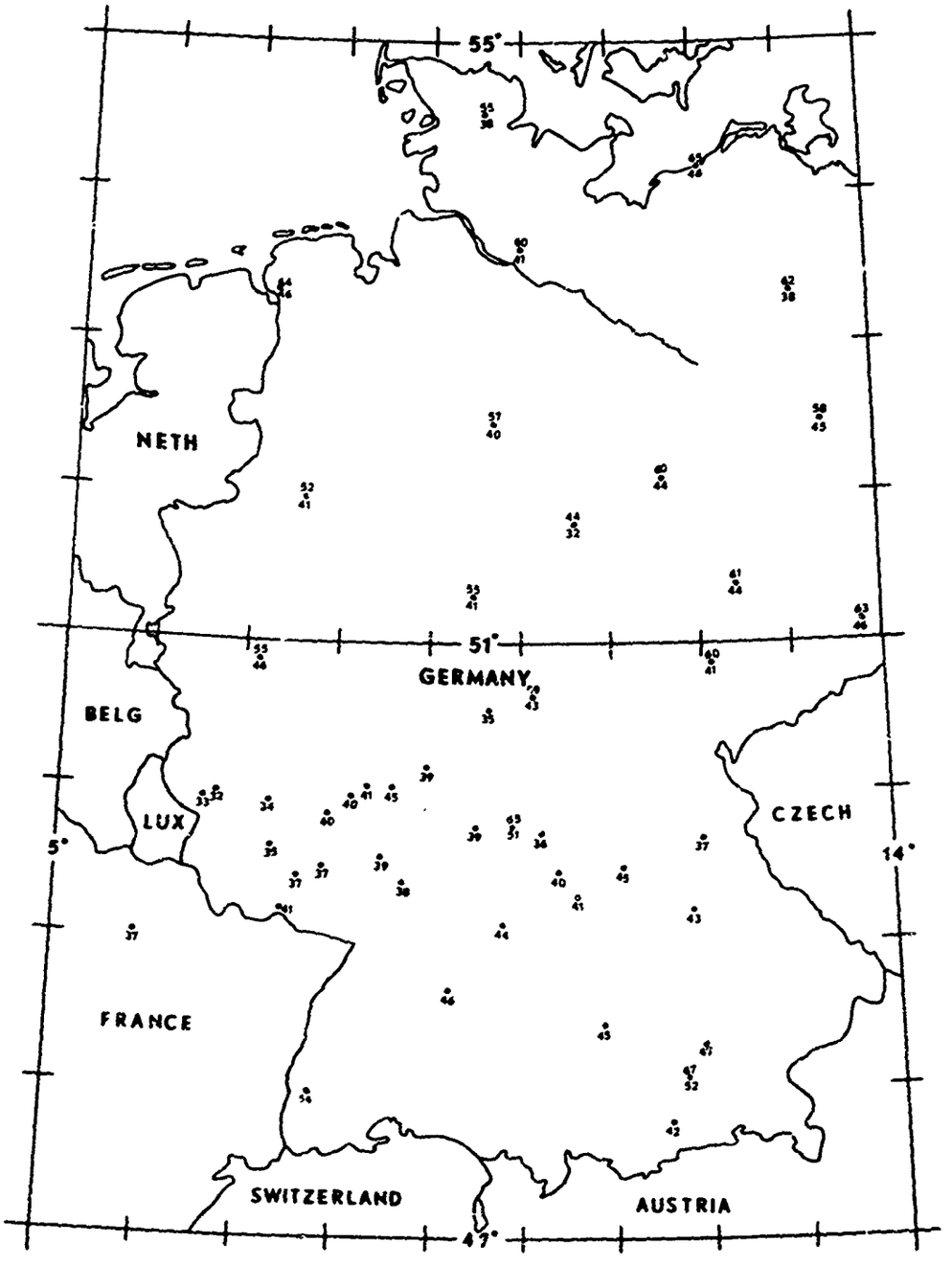

Figure 44. CFLOS Probabilities for Jul, 12-14 LST, 30° Elevation

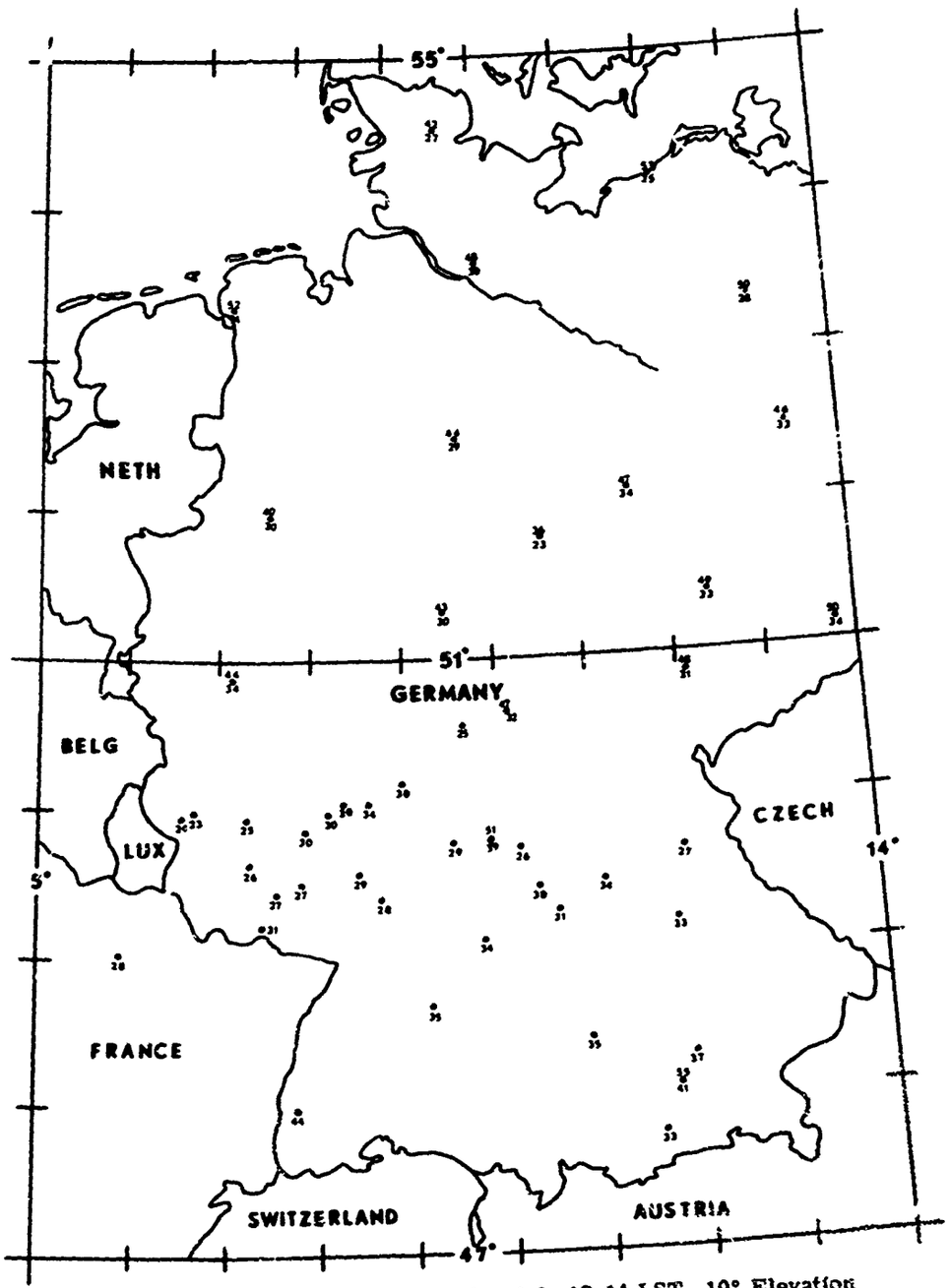

Figure 45. CFLOS Probabilities for Jul, 12-14 LST, 10° Elevation

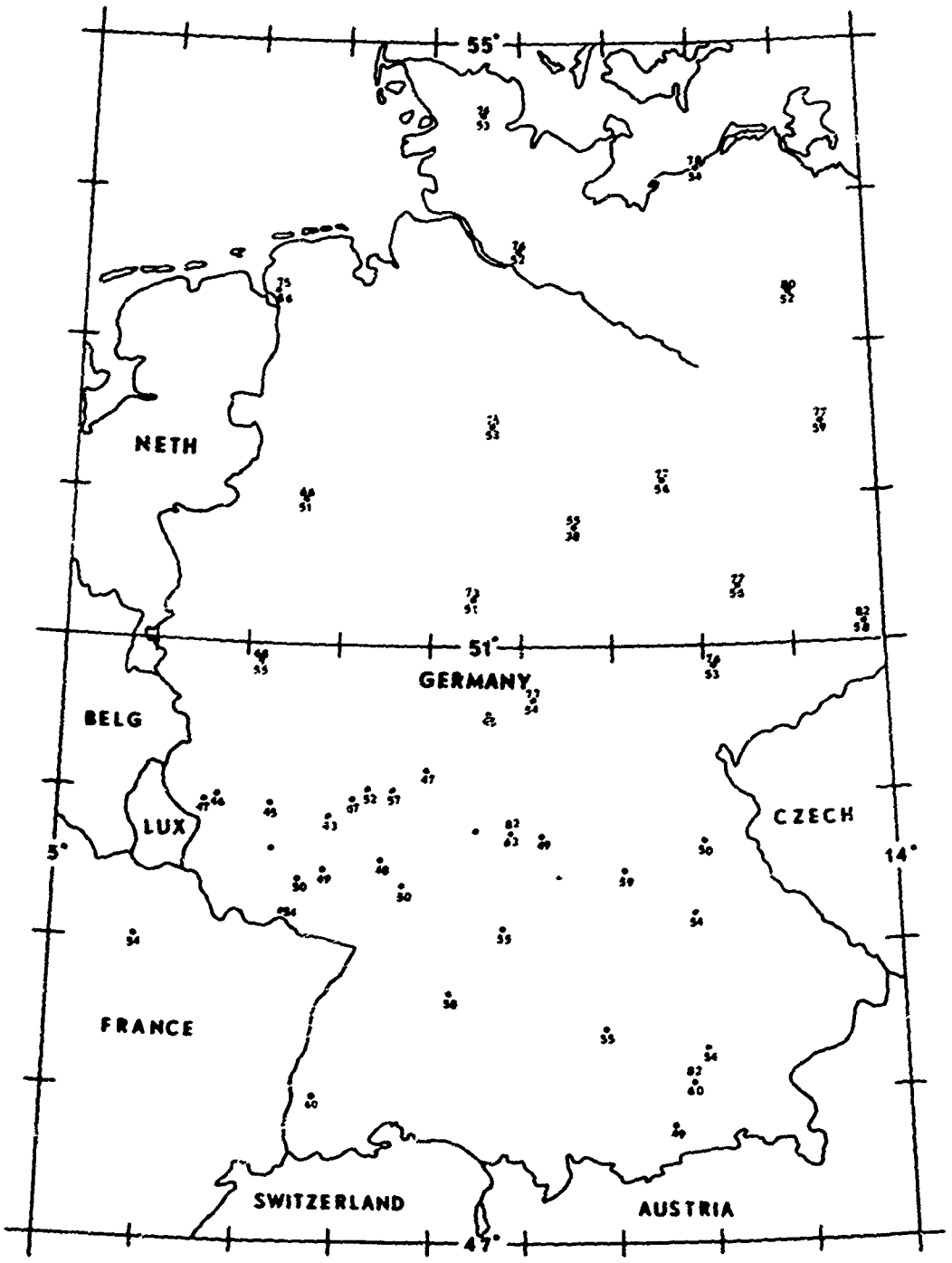

Figure 46. CFLOS Probabilities for Jul, 18-20 LST, 90° Elevation

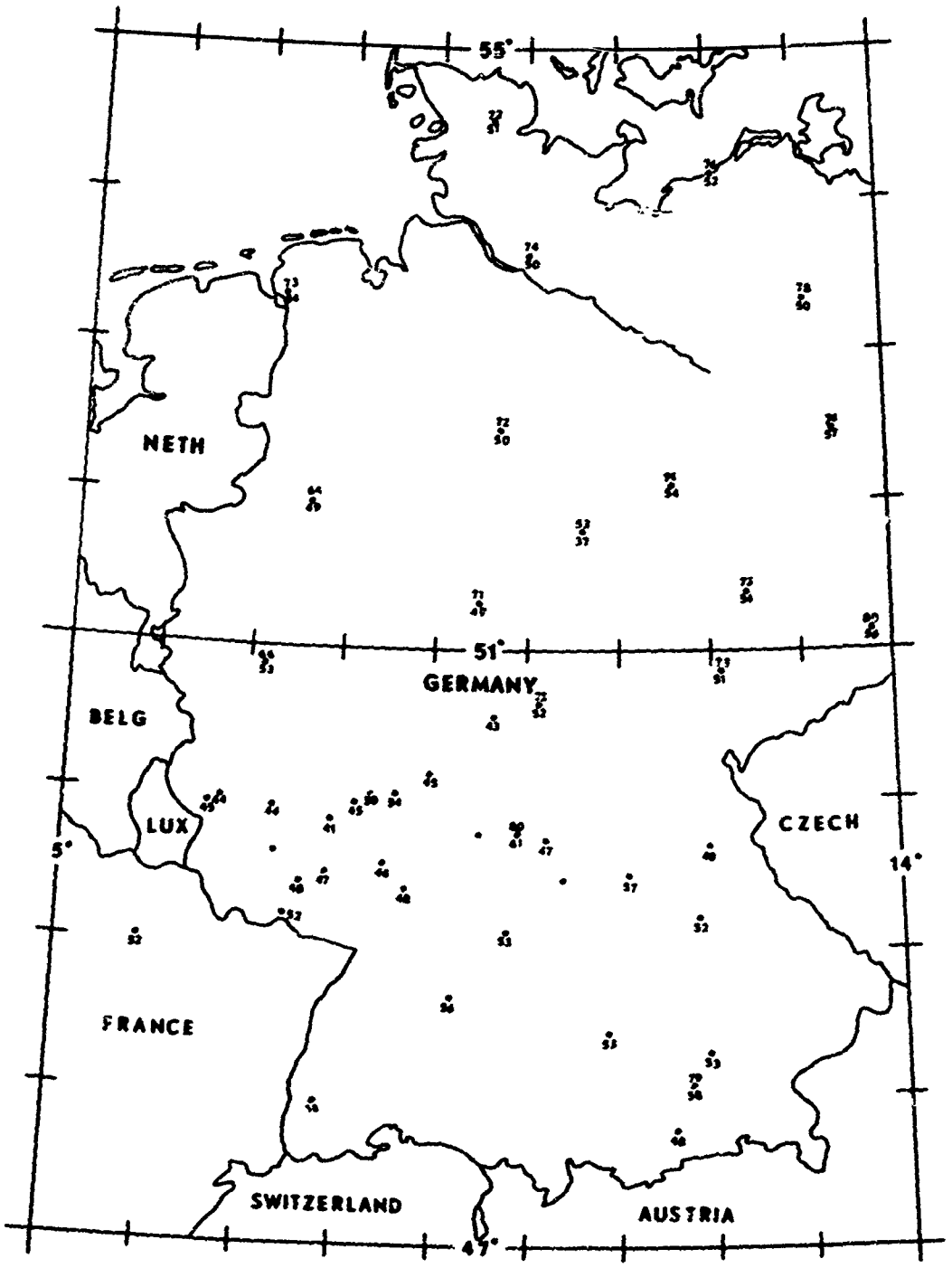

Figure 47. CFLOS Probabilities for Jul, 18-20 LST, 50° Elevation

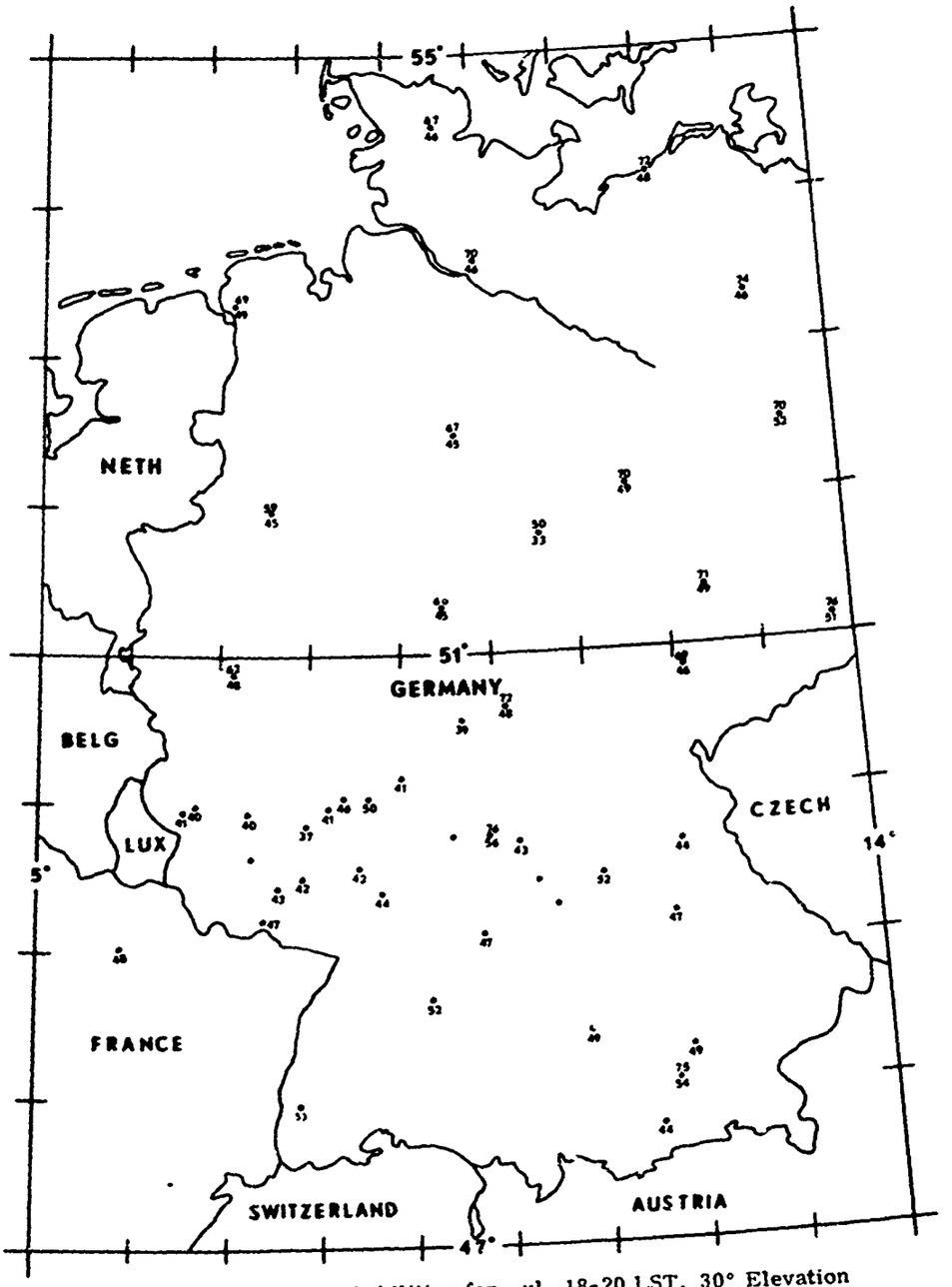

Figure 48. CFLOS Probabilities for ul, 18-20 LST, 30° Elevation

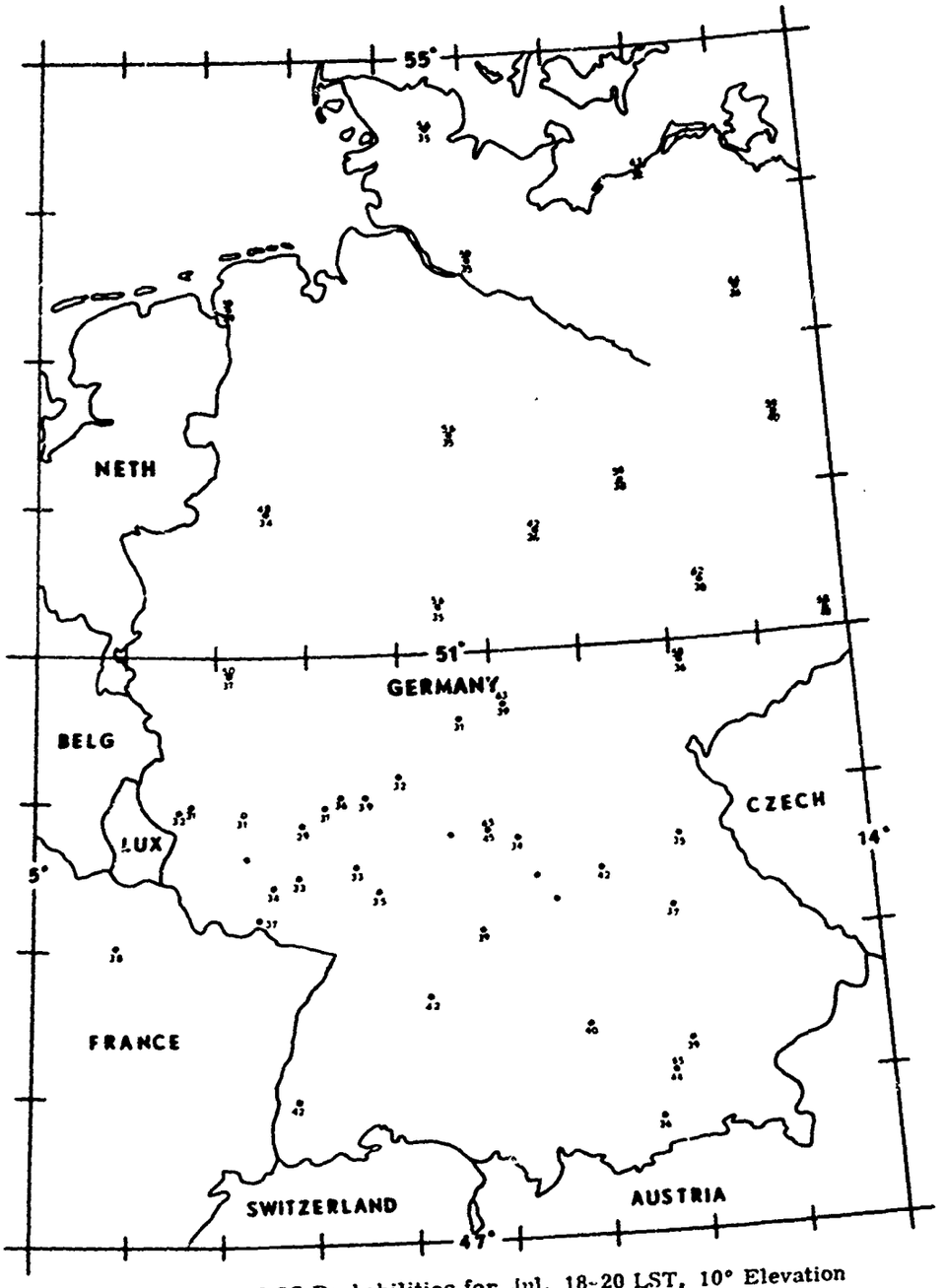

Figure 49. CFLOS Probabilities for Jul, 18-20 LST, 10° Elevation

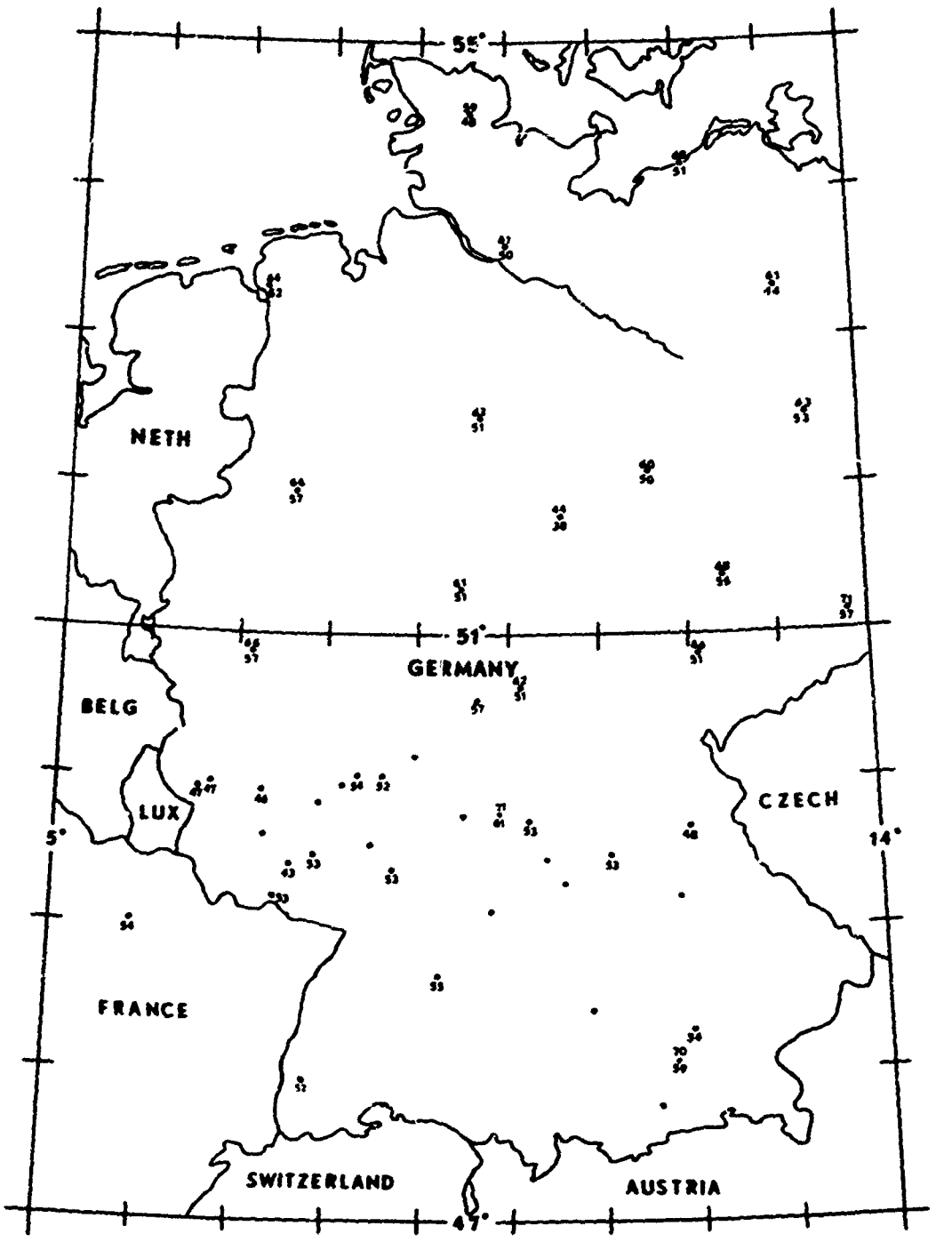

Figure 50. CFLOS Probabilities for Oct, 00-02 LST, 90° Elevation

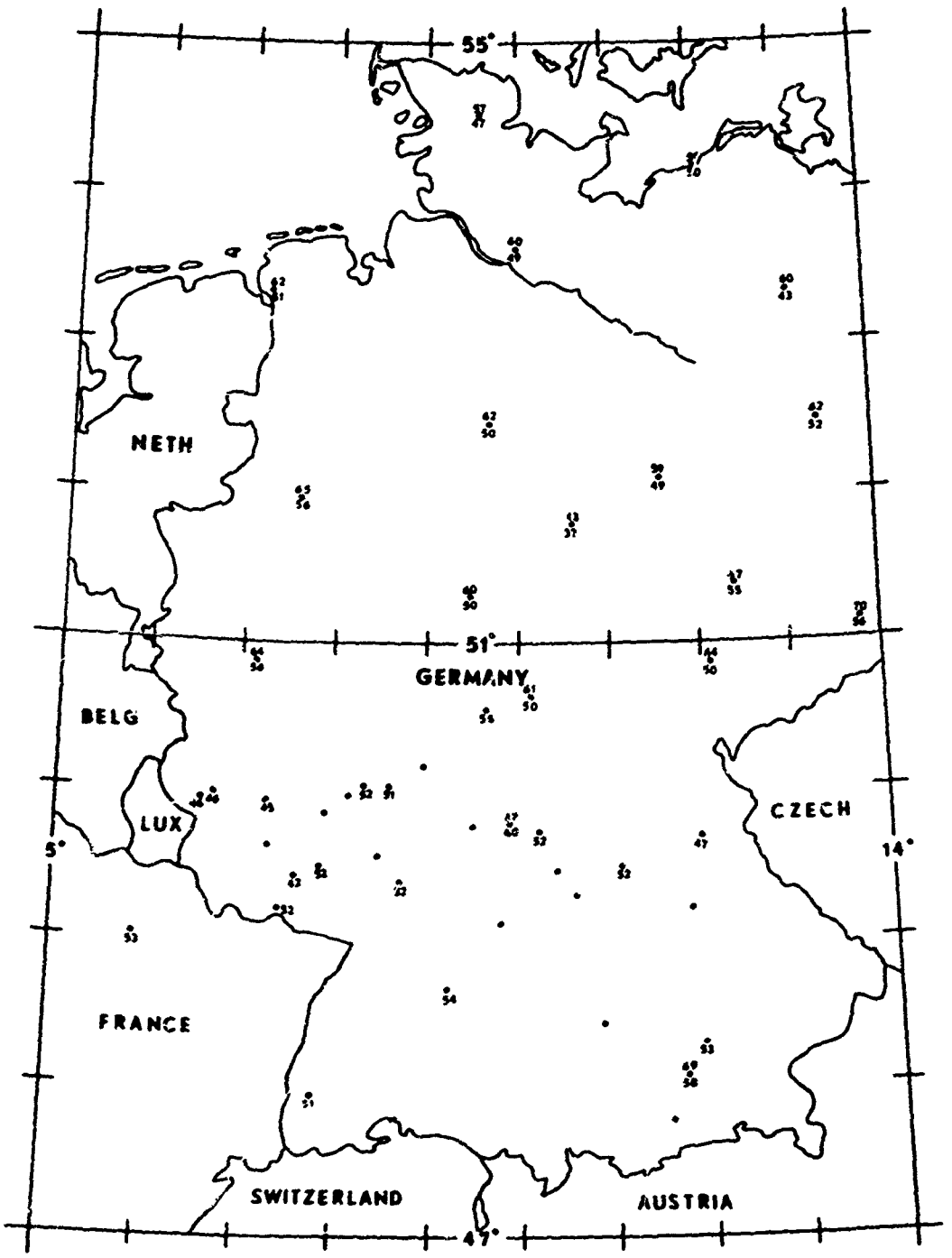

Figure 51. CFLCS Probabilities for Oct, 00-02 LST, 50° Elevation

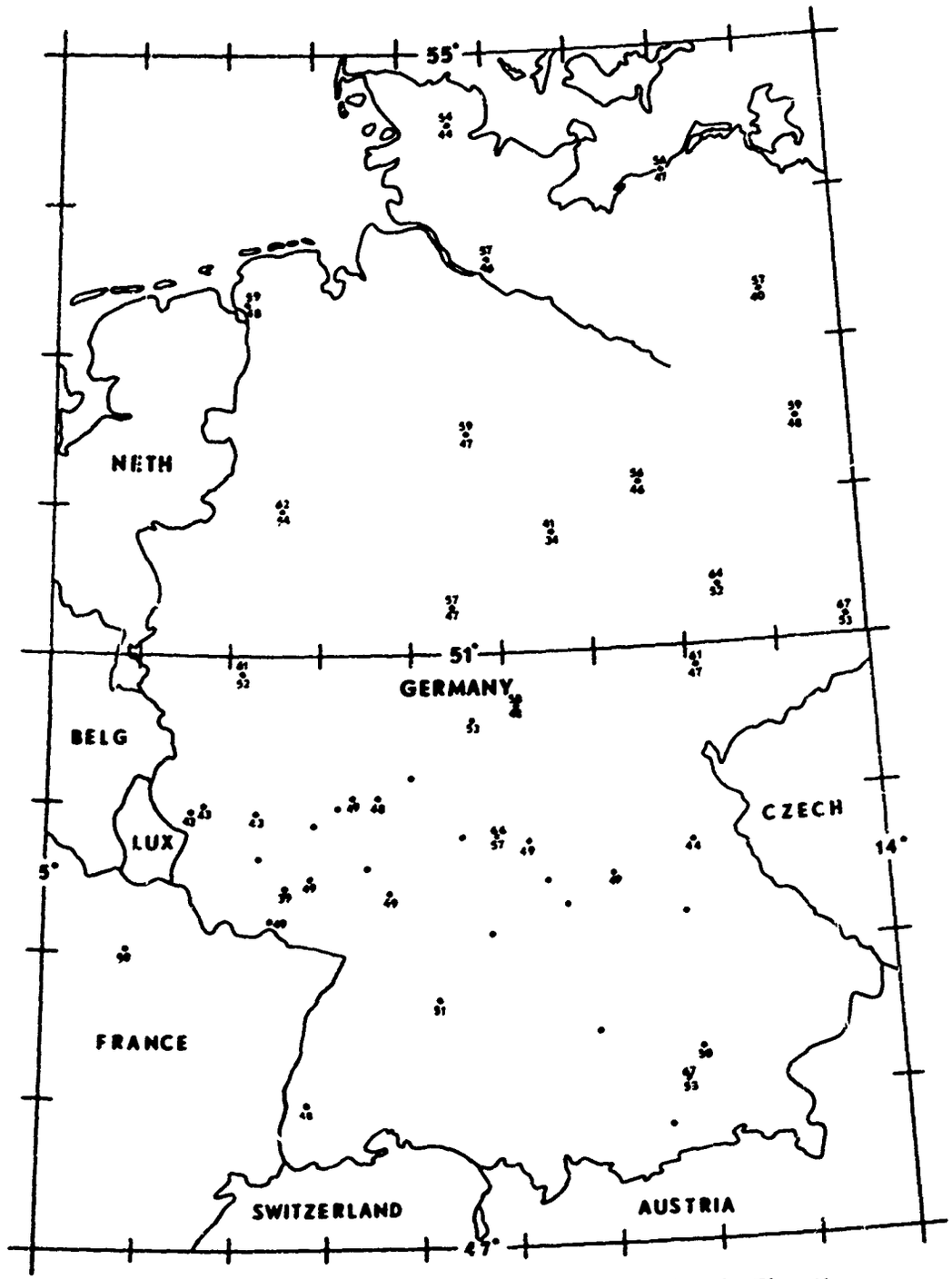

Figure 52. CFLOS Probabilities for Oct, 00-02 LST, 30° Elevation

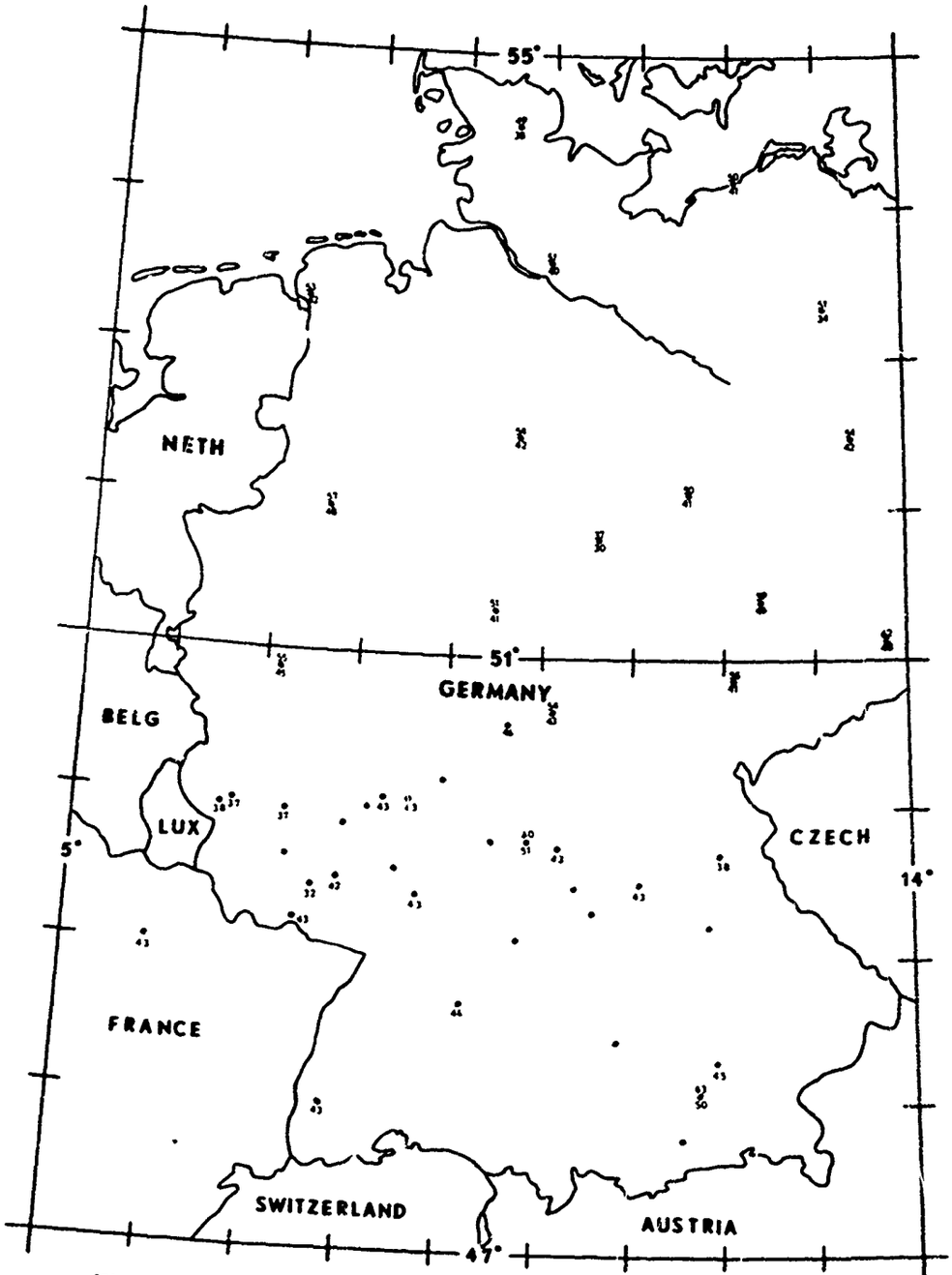

Figure 53. CFLOS Probabilities for Oct, 00-02 LST, 10° Elevation

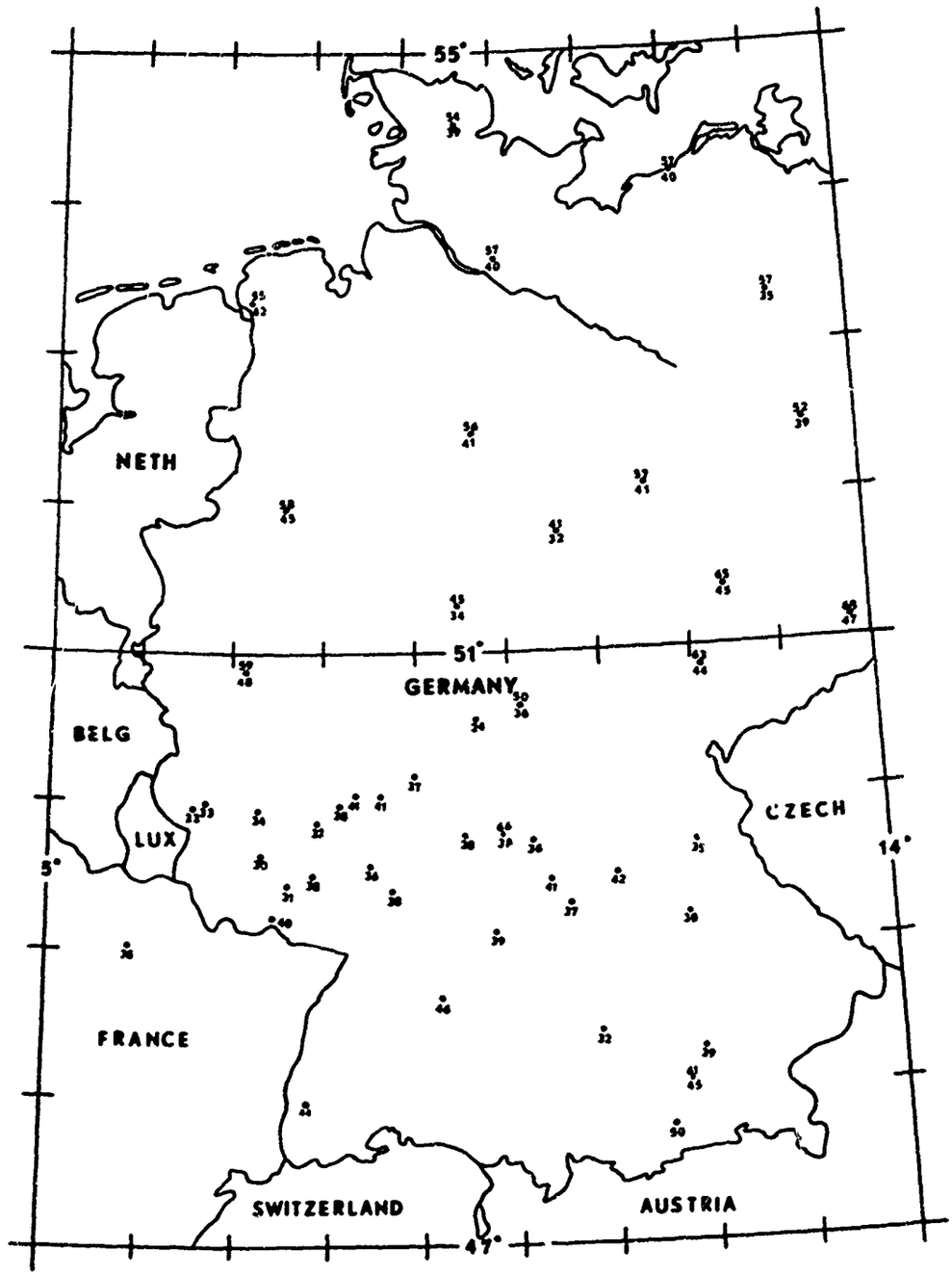

Figure 54. CFLOS Probabilities for Oct, 06-08 LST, 90° Elevation

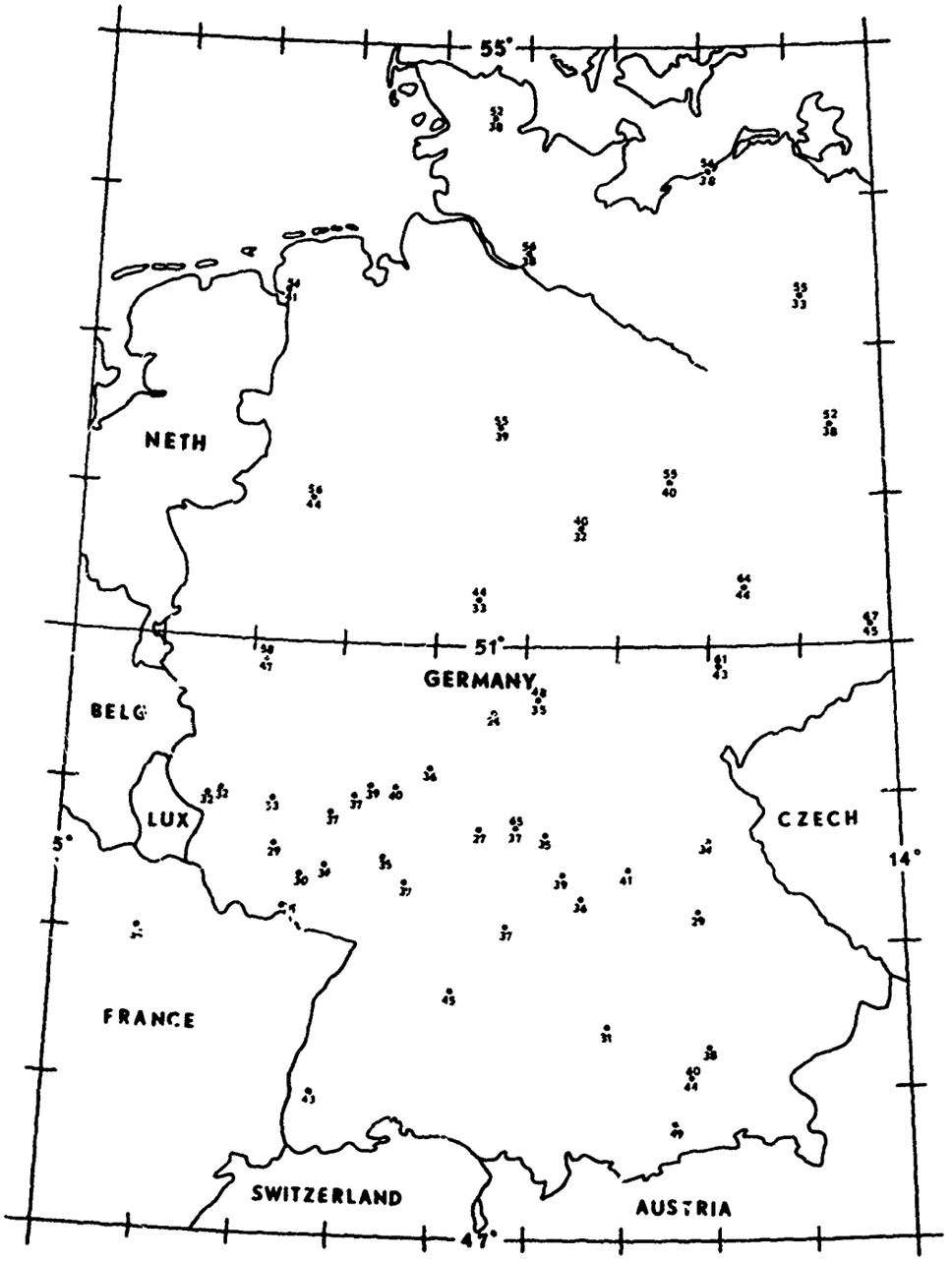

Figure 55. CFLOS Probabilities for Oct, 06-08 LST, 50° Elevation

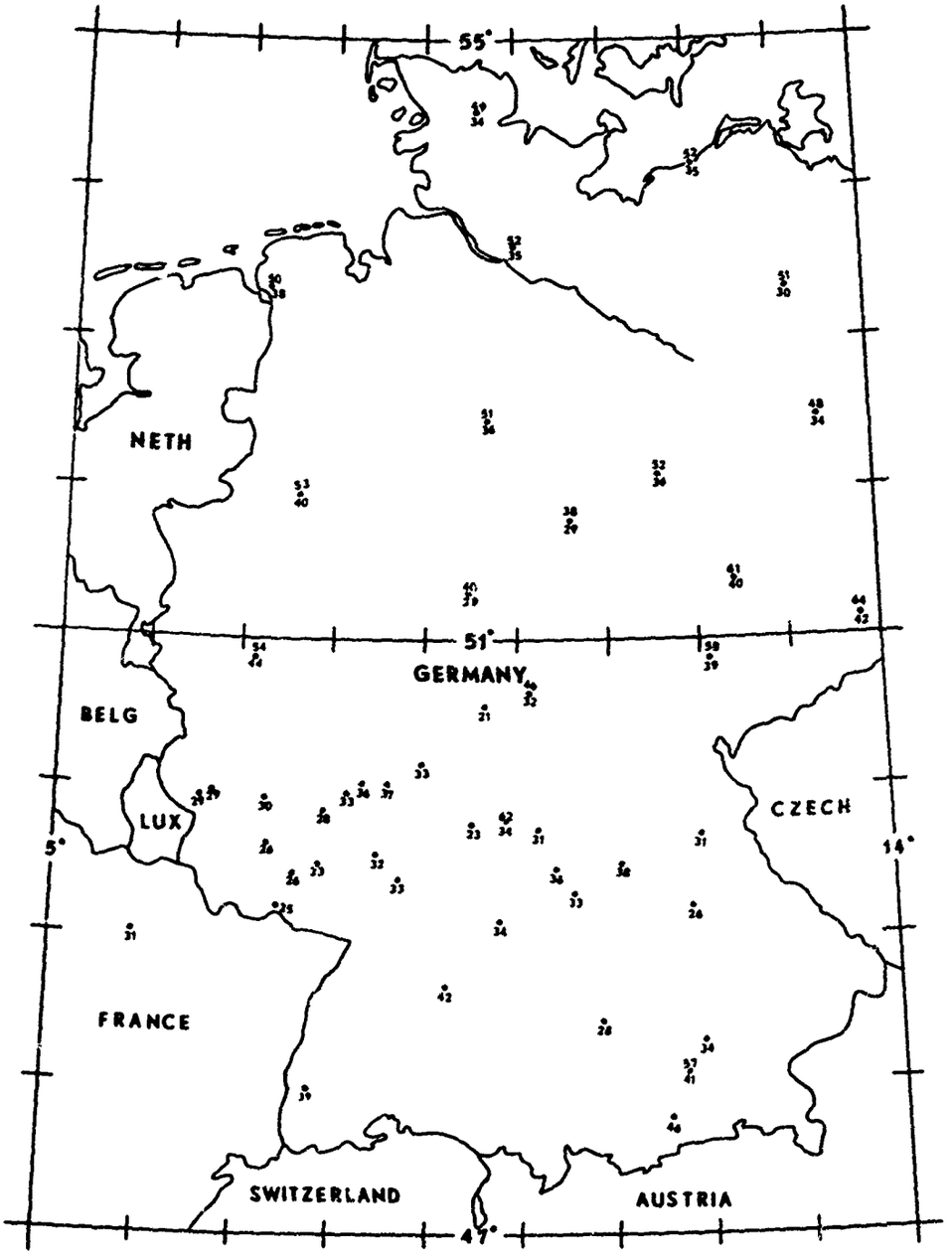

Figure 56. CFLOS Probabilities for Oct, 06-08 LST, 30° Elevation

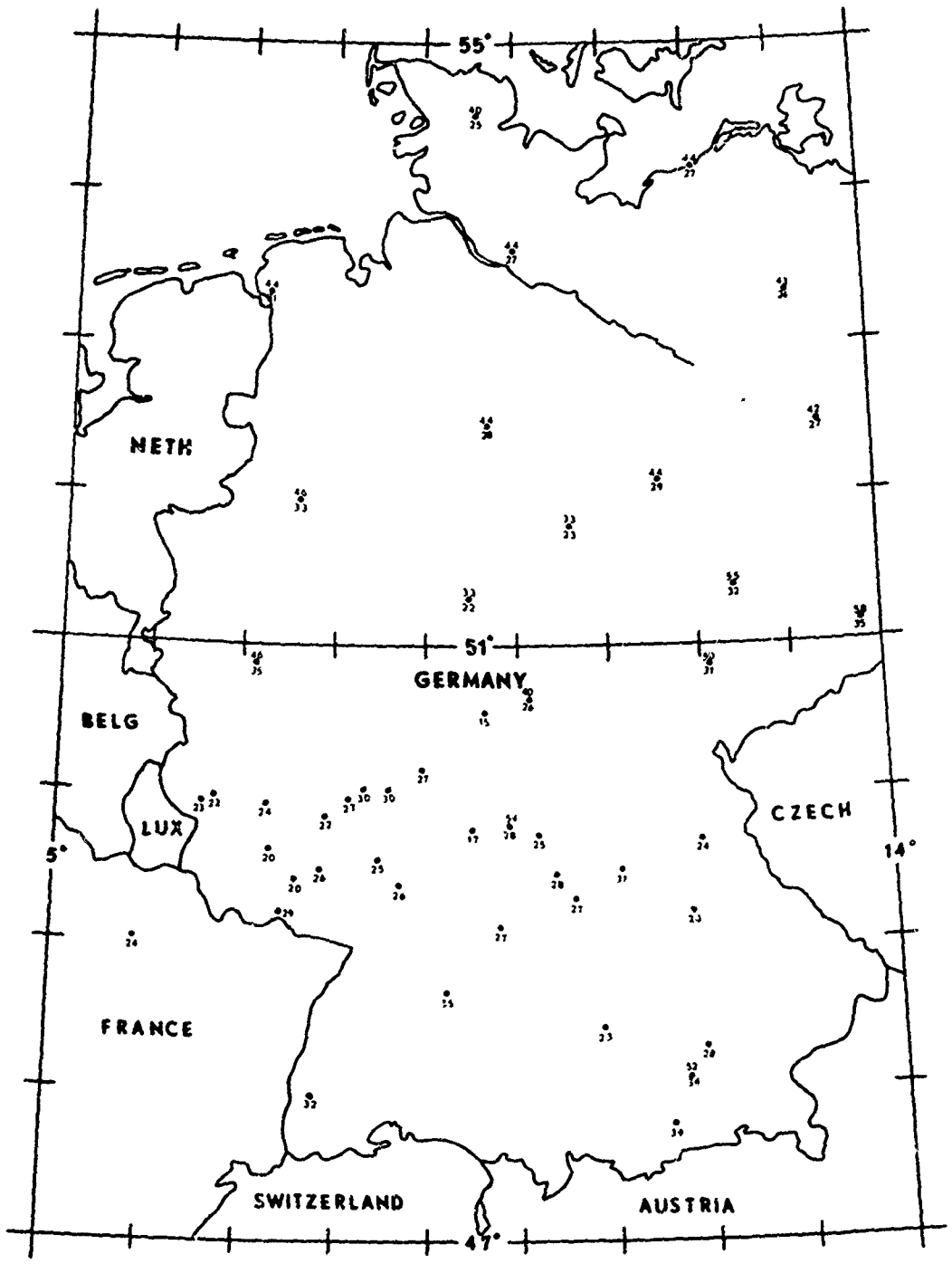

Figure 57. CI LOS Probabilities for Oct, 06-08 LST, 10° Elevation

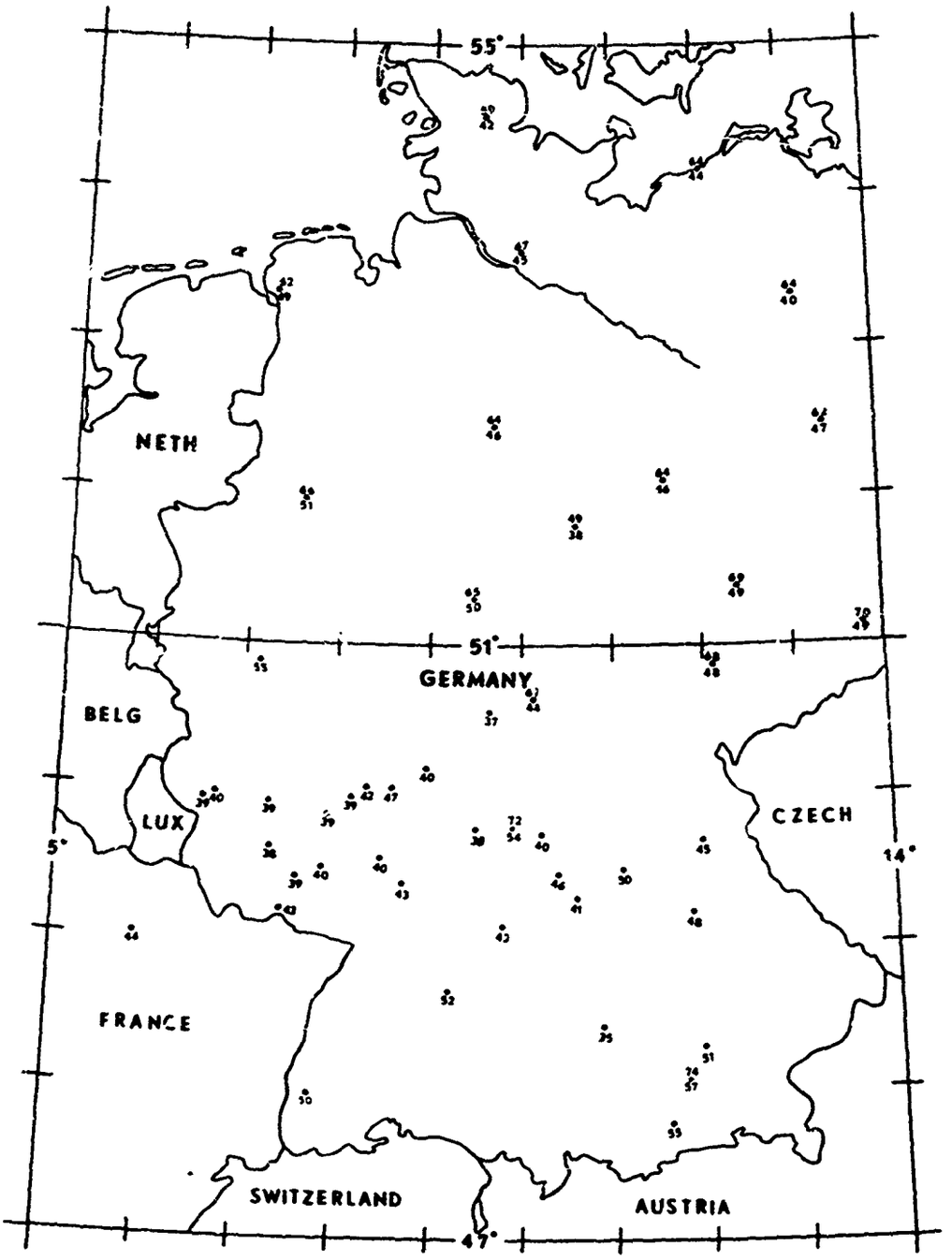

Figure 58. CFLOS Probabilities for Oct, 12-14 LST, 90° Elevation

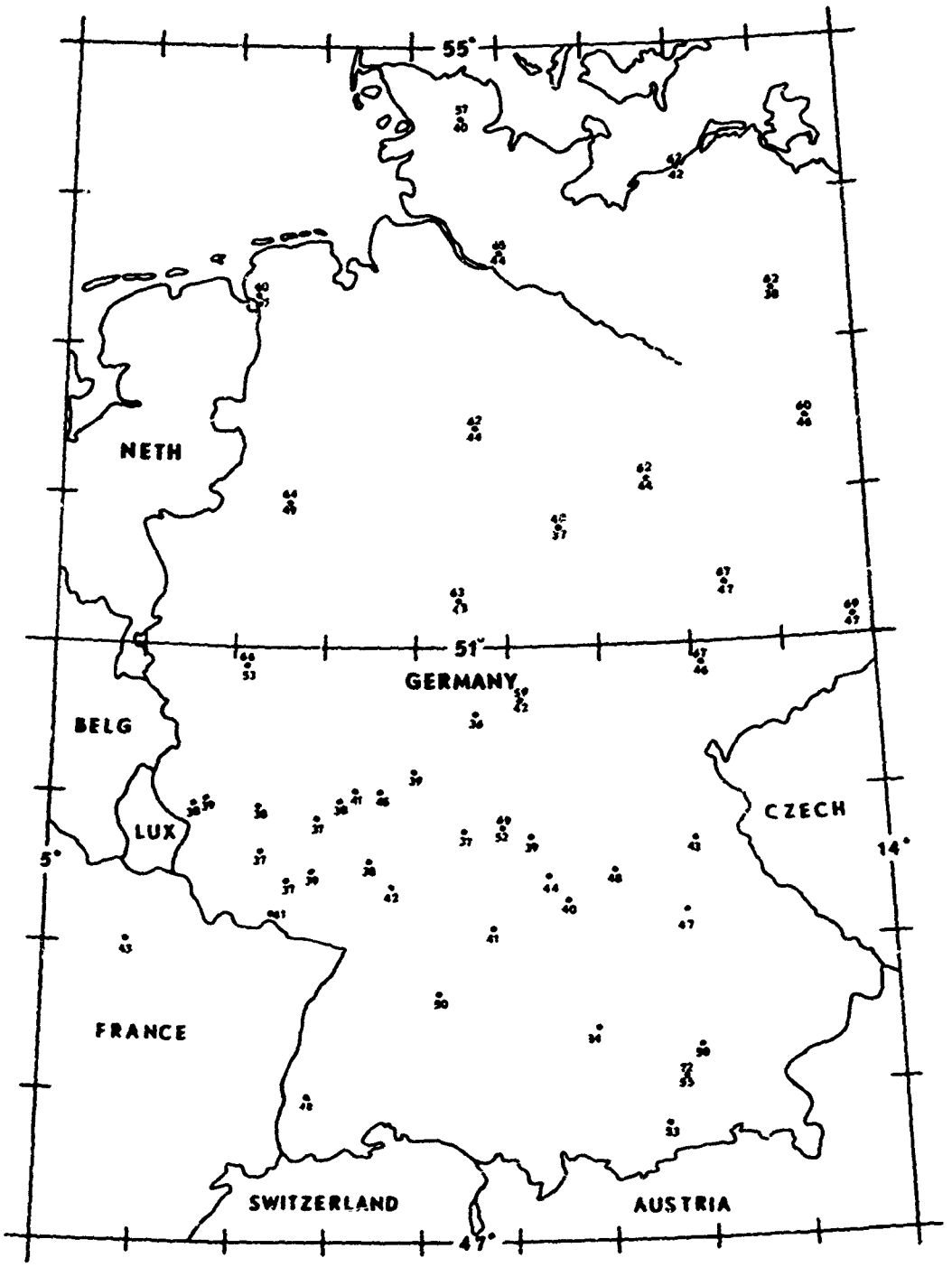

Figure 59. CFLOS Probabilities for Oct, 12-14 LST, 50° Elevation

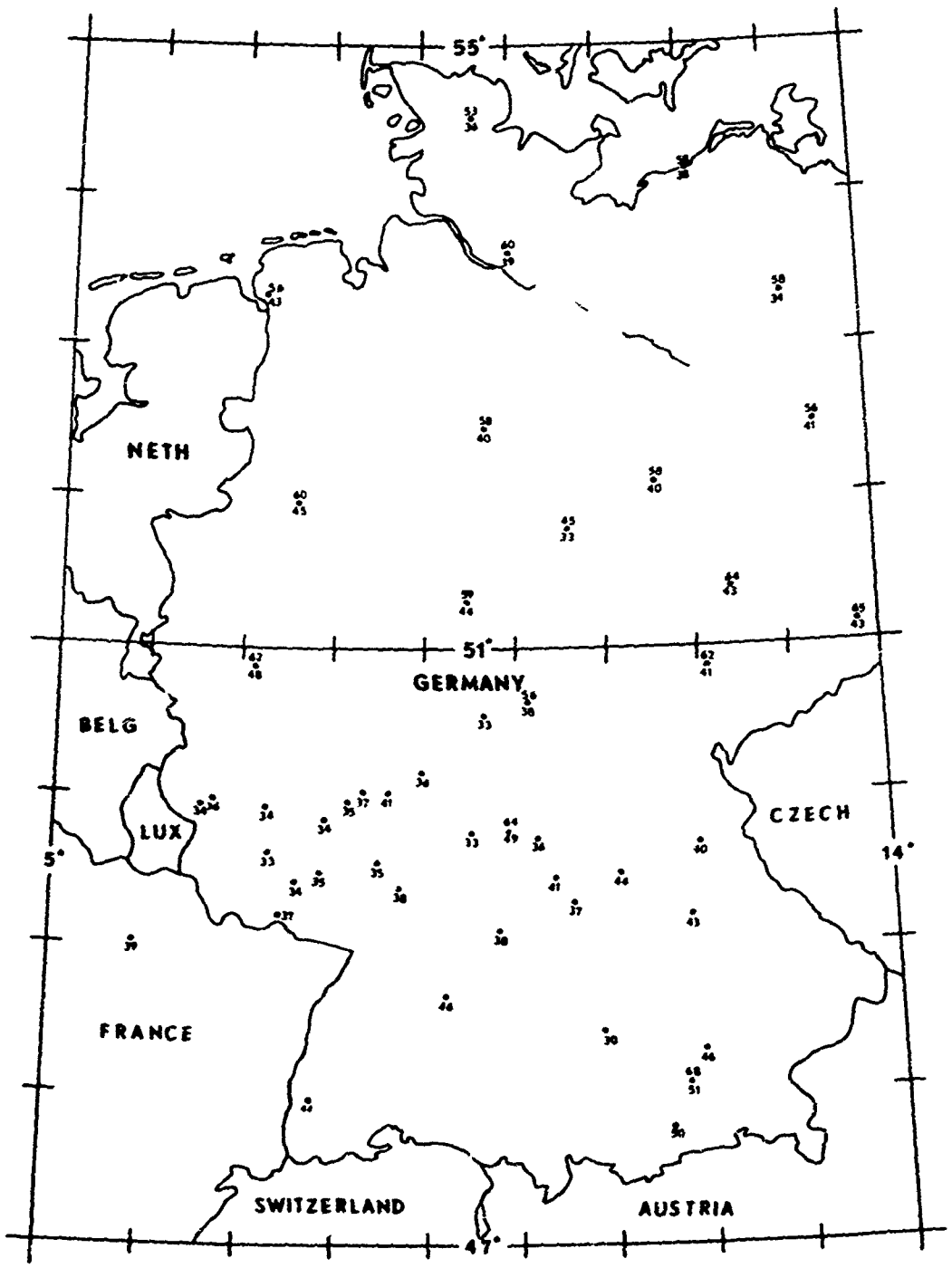

Figure 60. CFLOS Probabilities for Oct, 12-14 LST, 30° Elevation

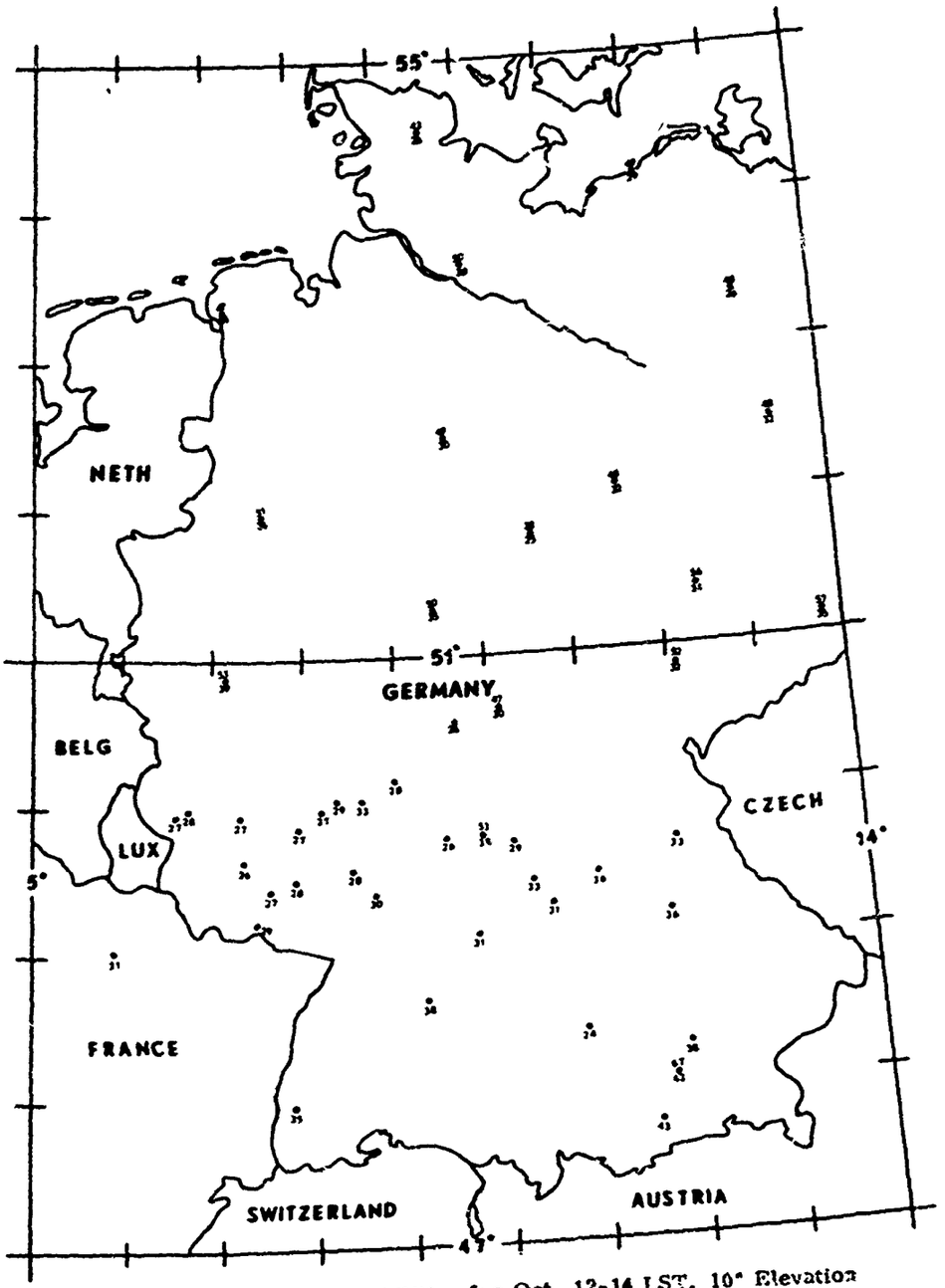

Figure 61. CFLOS Probabilities for Oct, 12-14 LST, 10° Elevation

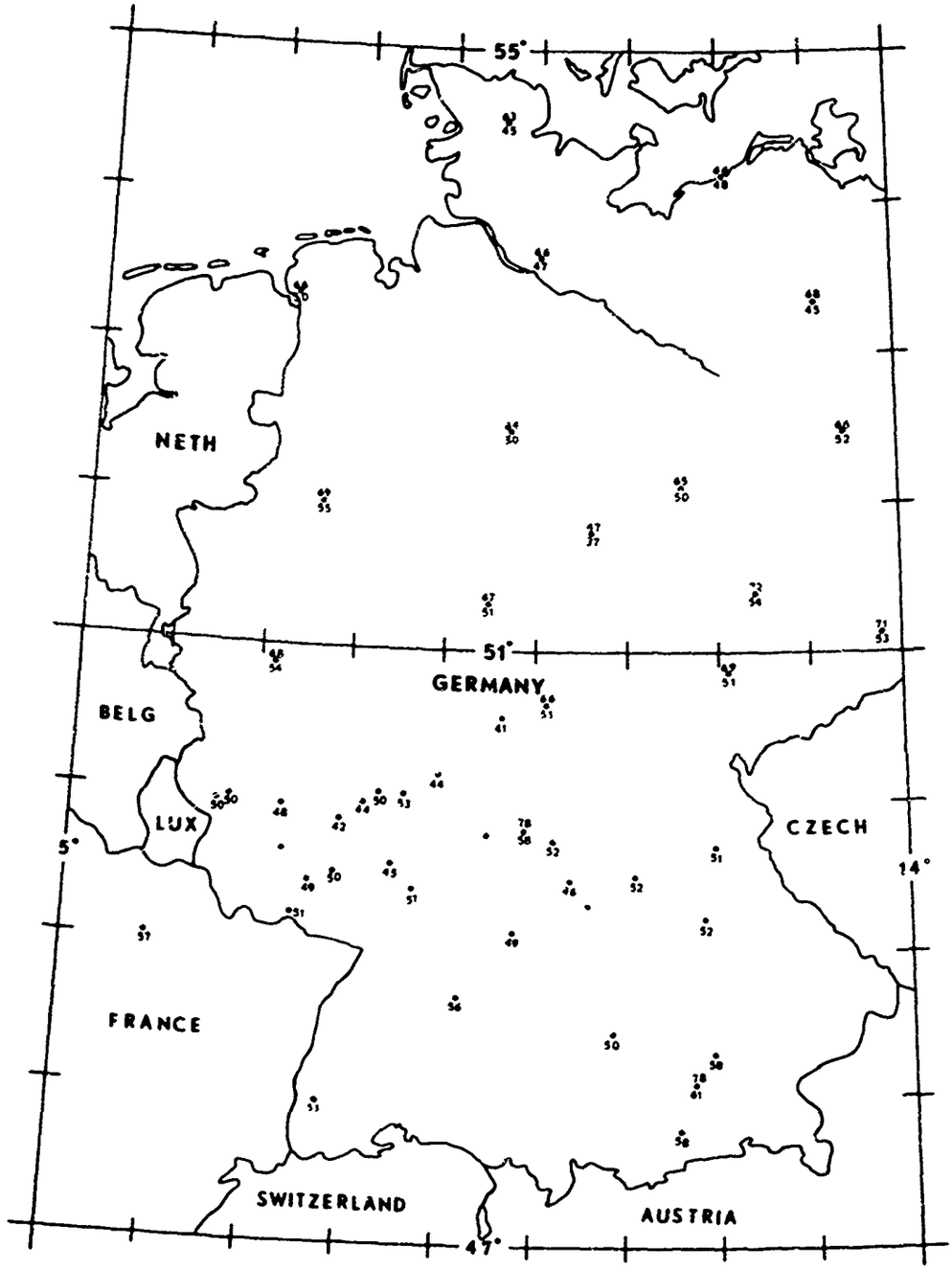

Figure 62. CFLOS Probabilities for Oct, 18-20 LST, 90° Elevation

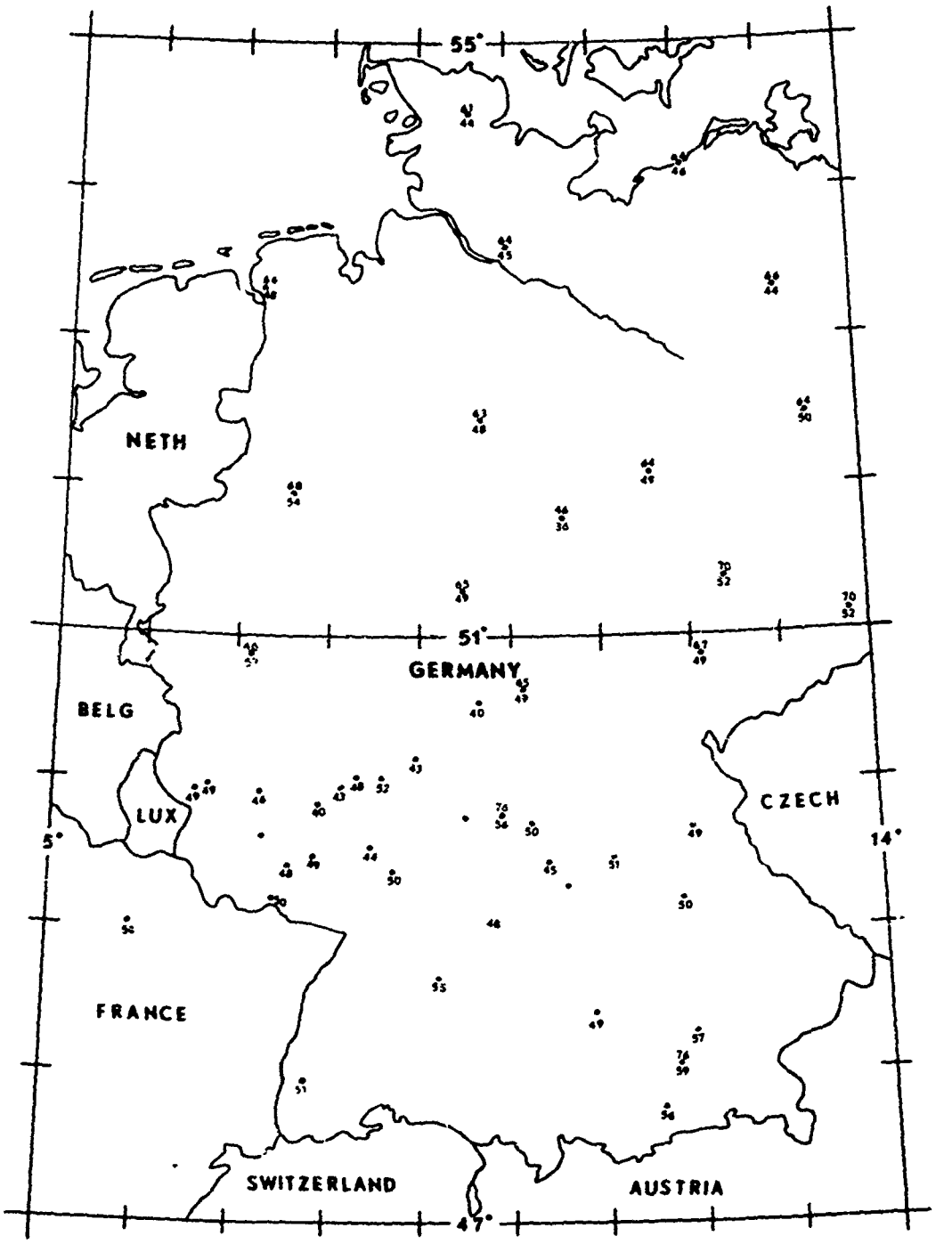

Figure 63. CFLOS Probabilities for Oct, 18-20 LST, 50° Elevation

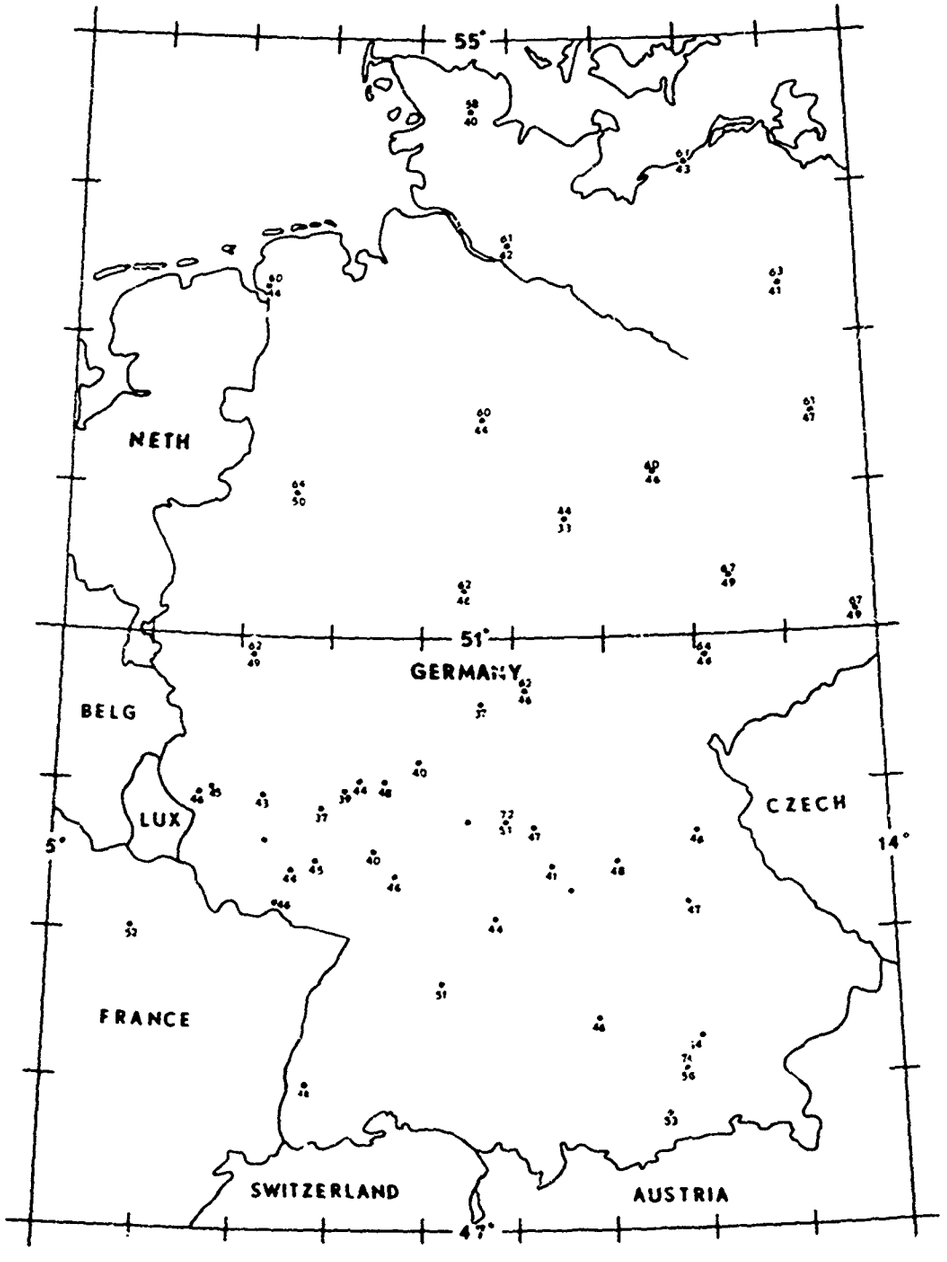

Figure C4. CFLOS Probabilities for Oct, 18-20 LST, 30° Elevation

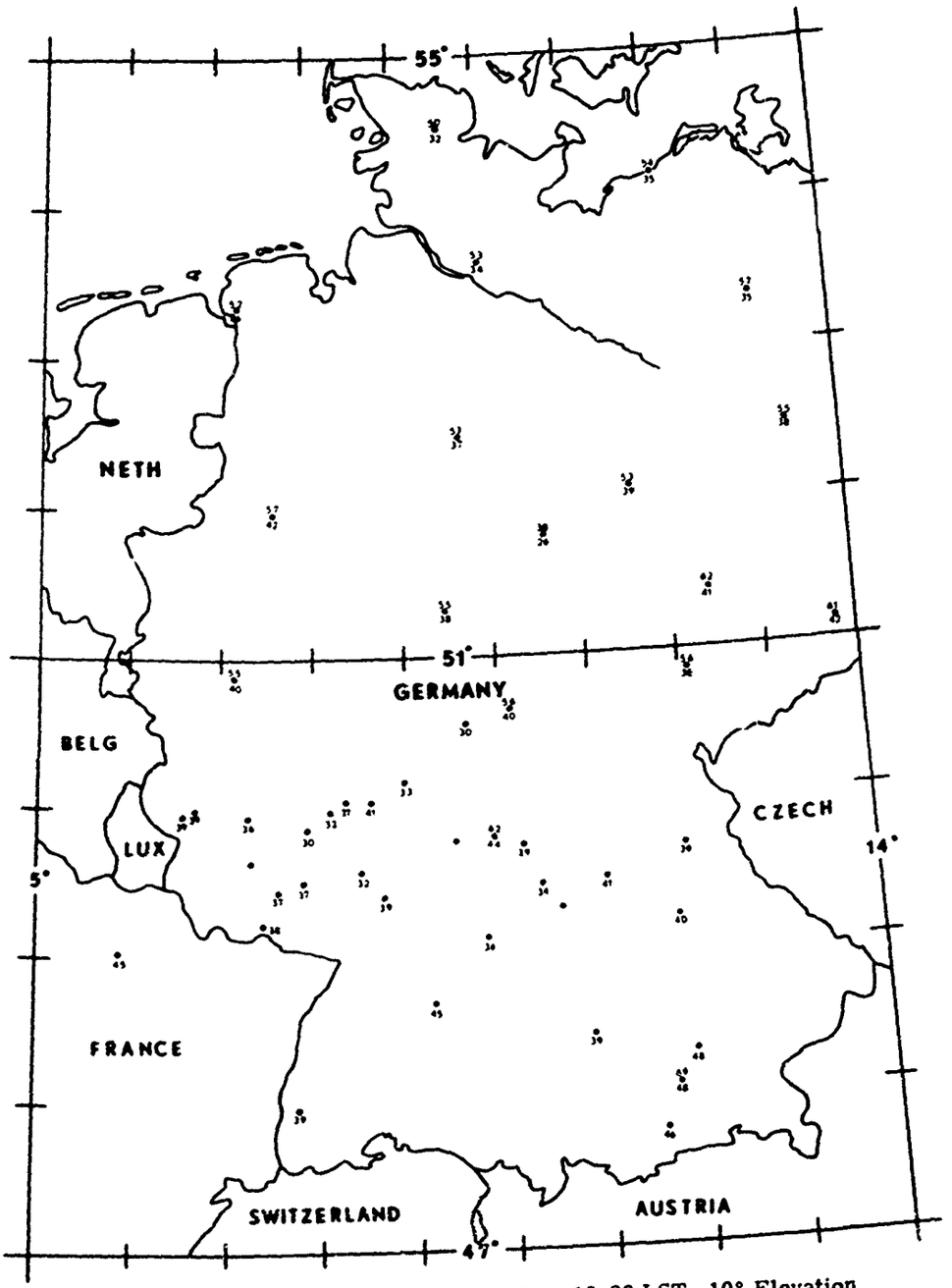

Figure 65. CFLOS Probabilities for Oct, 18-20 LST, 10° Elevation

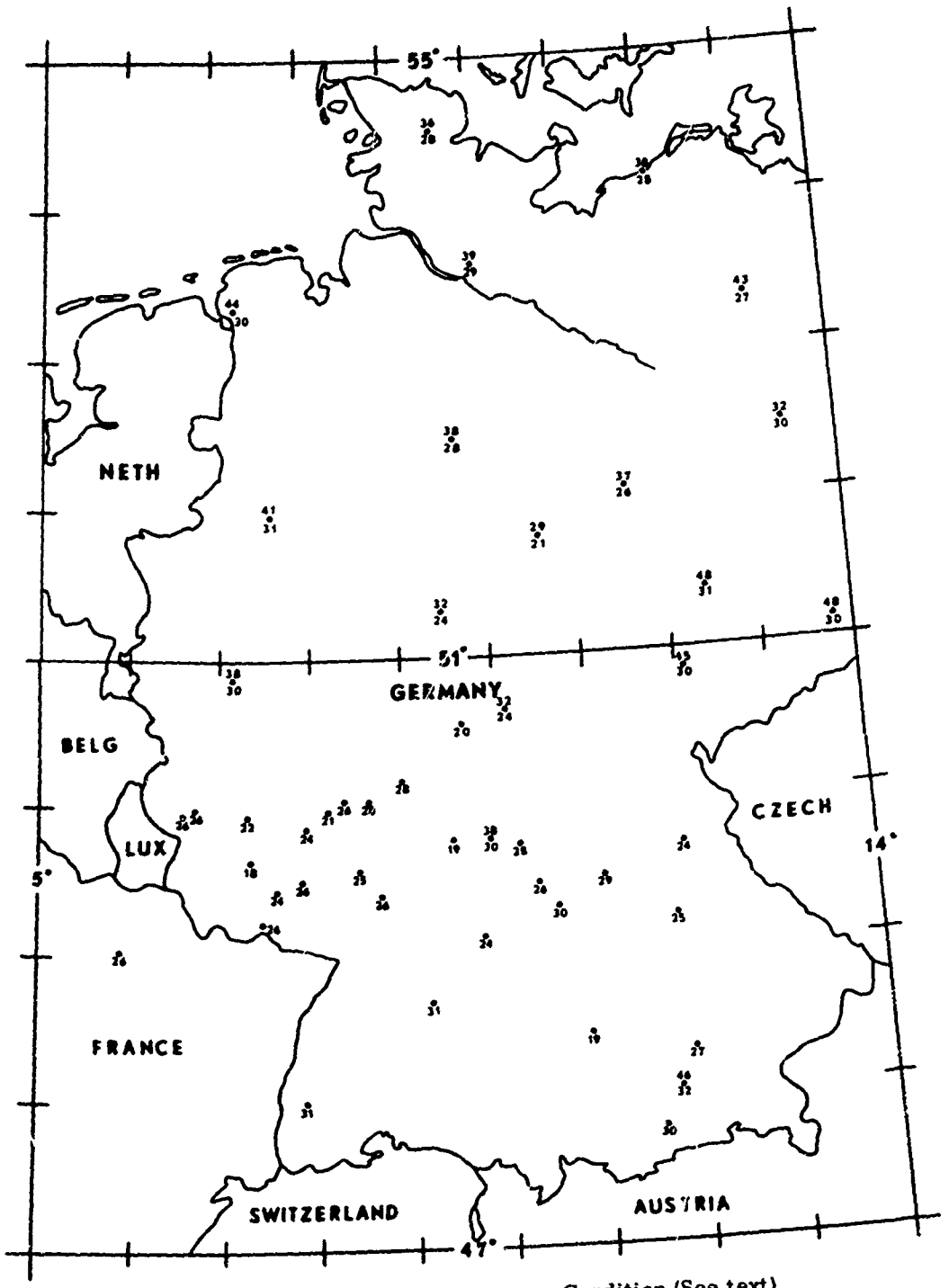

Figure 66. The Extreme Condition (See text)